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Studies on the Mechanisms of Phosphorus and Iron Absorption by Rice Plant

III. Effect of Aerations and Respiratory Inhibitors on the Phosphorus in Bleeding Sap.*

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(Received April 10, 1952)

I. Preface

The writers have studied phosphorus and iron absorption by the rice plant in order to make clear its nutrient absorption mechanism. In the course of this study they recognised a few phenomena from which it can be inferred that rice is, as compared with barley, characteristic in its absorption.[1][2]

Recently it is widely recognised that absorption of nutrient ions needs energy, and a great importance is attached to the respiration process by which crops obtain these energy. Thus aeration is an important factor in nutrient absorption with crops except rice whose aeration is seen to play no important role in nutrient absorption. Many studies have been made concerning the aeration of rice[3][5][12] and Taylor[13] has again take up the respiration of the root of rice plant as an important problem from the standpoint of anaerobic respiration.

It seems that the nutrient absorption by the rice plant is closely related with the peculiarities of its respiration system. In the present paper, therefore, the relations between the phosphorus absorption by the rice plant and its aeration or respiratory inhibitors, have been investigated as a means to know the cause of the peculiar phenomenon of phosphorus absorption by the rice plant.

To take up such a problem it is important to directly observe biochemical reaction in vibo, and many devices have hitherto been made for this purpose, but none of them is satisfactory, each having some defects with all its strong points.

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* The 78th report of the Institute for Agricultural Research, Tohoku University (1952).

In this study the bleeding sap produced by cutting stems is made an object of experiment in order to directly observe, more or less, biochemical reaction in vibo.

II. The Method for Experiment and its Results

1. Bleeding sap.

The phenomenon of bleeding, the phenomenon that the stem, cut a few centimeters above the root, exudes sap, has been known from an early date. Wieler[14] (1893) observed that the lack of oxygen inhibits bleeding, but after this the study in this field did not made a great progress. It was only after Speidels (1939) had observed the parallel relationship between bleeding and respiration that bleeding was recognised to be closely related with the general metabolic activity of the cell.

After Lundegardh[9] (1933) had investigated the relationship between respiration and anion absorption, published the so-called anion respiration theory, and taken up bleeding sap as a means to prove the truth of his theory, the phenomenon of bleeding was made clearer.

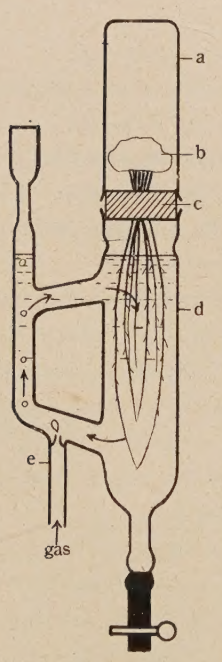

Fig. 1. Apparatus for bleeding examination.
a : glass cover
b : absorbent cotton
c : cork
d : vessel (contents : 120 cc)
e : opening for gas

It is as yet unknown what causes bleeding. It is a question to be solved in the future. But bleeding sap itself seems to be explained by the following words of Lundegardhs.[9] "Bleeding sap is not cell sap but the results of exudation of ion and water which pass through the protoplasms of living cells around vessels." "The process of the active inward transport of ion is no doubt an important part of the bleeding phenomenon, and this process clearly depends directly on aerobic respiration."

From the above, the existence of the close relationship between bleeding and nutrient absorption of roots is clear. This is the reason why the writers have taken up this sap in order to make clear phosphorus absorption by the rice plant. As for the chemical constitution of bleeding sap in rice plant, nothing is known about the phosphoric acid and the significance of the phosphoric acid in bleeding sap is not clear. So some experiments were made concerning this point. The results of the experiments are given below along with the method for experiment.

2. The Phosphoric Acid in Bleeding Sap.

For sample seedlings were used, as was reported[1], those grown about 10 cm high, the rice plants on nets and the barley on sand beds being made to sprout. The rice plants used were Norin No. 16 and the barley Aizu No. 2. These seedlings were cultivated with the cultutre solution shown in Table 1. In a concrete pots 80 *l* in content were fixed 72 sheaves, one sheaf including 10–20 plants and about a week they were cultured, one sheaf being regarded as an individual. The seedlings grown in this way used for the experiments.

Table 1. Constitution of culture solution (mg/*l*).

KNO_3	11 mg
$NH_4H_2PO_4$	8
NH_4NO_3	20
$CaCl_2 \cdot 6H_2O$	19
$MgSO_4 \cdot 7H_2O$	23

Table 2. Constitution of culture solution for experiment (mg/*l*).

Names of divisions	P_2O_5	$CaH_4(PO_4)$	Common ingredients
P_0	0	0	$(NH_4)_2SO_4$: 90
P_{20}	20	34	$Ca(NO_3)_2$: 30
P_{100}	100	171	$Mg(NO_3)_2$: 80
P_{150}	150	246	KNO_3 : 73

The culture solutions used for the bleeding experiments differed according to the purposes of experiments, but the chief solutions were, as shown in Table 2, four divisions such as P_2O_5 : 0,20,100,150 p.p.m.

To collect bleeding sap Lundegardh's method[8] was adopted. In the experiment vessel as showing in Figure 1 were fixed 10–20 of seedlings in a sheaf and immediately after that their stems were cut 2 cm hight from the roots and their cut ends were covered with cotton, a long and narrow beaker being put on them in order to prevent evaporation. After the operation the absorbent cotton was weighed, and from the difference between its weight and that of the absorbent cotton before the operations the quantity of bleeding sap was measured and the PO_4 extracted from the cotton with distilled water was quantitatively determined.

As stated above, each sheaf was made of 10–20 seedlings in order to get rid of the difference in the quantity of bleeding sap. It was difficult, however, to grow the seedlings under any fixed conditions because they were cultivated in a green house.

The relations between the ages of seedlings or their root weight and bleeding quantity were examined but any proportional relations could not be recognized between them as seen in Table 3. Thus the quantity of bleeding sap was not parallel to the age. As for the root weight it had no direct relation with the quantity of bleeding sap. But the causes for this were not clear, but some of them were considered to be inevitable. So in this study the results of a series of experiments conducted on the same day were taken up, and different experiment days were not compared with reagerd to the quantity of bleeding sap.

Table 3. Relations between number of culture days, root weight, and qauntities of bleeding sap.

Culture days	9 days	11 days	15 days	20 days
Bleeding sap	358 mg	470 mg	180 mg	420 mg
Root weight	1.1 g	1.1 g	2.8 g	
Bleeding sap	77 mg	303 mg	328 mg	

To conduct on experiment with reagerd to the phosphorus contained in bleeding sap it is necessary to know the relations between the phosphorus in the culture solutions for the bleeding and the phosphorus contained in bleeding sap. According to Lundegardh[9] the phosphorus contained in bleeding sap varies in quantity more or less according to the presence and absence of phosphorus in the

Table 4. Relation between phosphrus in bleeding sap and that in solution (experiment hour 2 hours).

No	Pre-culture	Solution for bleeding	Bleeding sap (mg)	PO_4 in sap (mg)	Density* of PO_4 in sap
		i. **Rice**			
(a)		July 25, 1951			
1	3 days P_0	P_{20}	318	0.171	0.53
2	〃	〃	369	0.190	0.51
3	〃	P_0	346	0.009	0.03
4	〃	〃	348	0.009	0.03
(b)		Aug. 8, 1951			
1	3 days P_0	P_{20}	358	0.121	0.33
2	〃	〃	346	0.131	0.37
3	〃	H_2O	141	0.011	0.09
4	〃	〃	146	0.012	0.08

(c) Aug. 27, 1951

1	3 days P_{20}	H_2O	157	0.015	0.09
2	〃	〃	156	0.014	0.09
3	3 days P_{100}	〃	115	0.015	0.13
4	〃	〃	154	0.025	0.16
5	3 days P_{20}	P_0	512	0.046	0.08
6	〃	〃	566	0.046	0.08
7	3 days P_{100}	P_0	454	0.051	0.11
8	〃	〃	577	0.066	0.11

ii. **Barley**

Aug. 2, 1951

1	3 days P_0	P_{150}	203	0 037	0.18
2	〃	〃	227	0.042	0.18
3	〃	P_0	221	0.011	0.04
4	〃	〃	248	0.013	0.05

Note : *Density is given by $\frac{PO_4}{\text{bleeding}} \times 100$.

solution, but generally the phosphorus which is derived from the stored phosphorus in the root — the phosphorus about 2 m mol in density is present in bleeding sap. To make this clear the following experiments were conducted. The relations between the phosphorus in the culture solution for bleeding and the stored phosphours in the root were examined with the experiments shown in Table 4.

As is clear from Table 4, i (a), in the case of a root previously cultivated without phosphorus for 3 days, if the culture solution for bleeding contains phosphours, the phosphorus in the bleeding sap was greater in quantity and density than in the case of a root set in the solution lacking phosphorus alone. This shows that the phosphorus in the outer medium for a short time (2 hours after the stems were cut) is closely related with the phosphorus contained in the bleeding sap. When the culture solution for bleeding was distilled water (Table 4, i (b)) the bleeding sap itself was reduced to half, not to speak of the phosphorus in the bleeding sap. It is clear from this that, apart from the pre-culture, the inorganic ingredients contained in the culture solution used during the experiment period had a direct influence upon the quantity and constitution of the bleeding sap.

Then the expreiment shown in Table 4, i (c) was carried out for the purpose of making clear the relations between the phosphorus absorbed by the rice plant during the pre-culture period and the phosphorus in the bleeding sap. Rice plants were previously cultivated with P_{20} and P_{100} for 3 days. Then the seedlings were set in the experiment vessel without phosphorus and in distilled water. The bleeding sap of plants set in distilled water was, as in the case of (b), was reduced to less than half in quantity, as compared with that of plants set in the culture solution without phosphorus. The PO_4 contained in the bleeding sap of seedlings

pre-cultured in the division of P_{100} was more in quantity than in the divisions of P_{20}. The phosphorus supplied to the seedlings in the pre-culture seemed to have had some effect. In such an experiment as this the phosphorus supplied during the pre-culture must be taken into consideration (The effect of the pre-culture is to be described below). At any rate these results show that the bleeding sap is influenced by the culture solution used during the experiment period, and the phosphorus contained in the bleeding sap is closely related with the phosphorus in the culture solution for bleeding, though it is not known whether directly or indirectly.*

The results of the same experiments with barley are shown in Table 4, ii. In the case of barley the increase ratio of the phosuphors is less than in the case of rice plants. From this it is clear that the phosphorus absorption by the rice plant is different from that by the barley plant.

3. Relations between Aeration and Phosphorus in Bleeding Sap.

As Wieler[14] observed that the bleeding decreased rapidly when oxygen supply was stopped, this phenomenon seems to have a close relationship with aeration. It has been said that the rapid decrease of the bleeding sap after the stem was cut occurs owing to due consideration not having been given to aeration. Lundegårdh[8] considered the cuases for this to be the lack of aeration and clogging up of the vessels near the wound, and succeeded in miantaining the bleeding phenomenon for a long time by making a new cut end every 2 hours and maintainig

Table 5. Aeration and bleeding (Rice).

Aug. 6, 1951

Period		Oxygen circulation			Nitrogen circulation		
		Bleeding sap (mg)	PO_4 in sap (mg)	Density of PO_4 in sap	Bleeding sap (mg)	PO_4 in (mg)	Density of PO_4 in sap
The 1st period (11.20a.m. -1.20p.m.)	a	448	0.123	0.25	568	0.169	0.28
	b	444	0.104		532	0.147	
The 2nd period (1.25- 3.25p.m.)	a	85	0.013	0.19	70	0.012	0.15
	b	50	trace		90	0.013	
The 3rd period (3.30- 5.30p.m.)	a	43	—	—	49	—	—
	b	63	—	—	54	—	

Note: For culture solution was used P_{100} boiled and then cooled, letting oxygen gas and nitrogen gas run through it.

* In an experiment with P^{32} (unpublished) both direct and indirect relations were observed.

Table 6. Aeration and bleeding (Barley).

Oct. 9, 1951

Period		Oxygen circulation			Nitrogen circulation		
		Bleeding sap (mg)	PO_4 in sap (mg)	Density of PO_4 in salp	Bleeding sap (mg)	PO_4 in sap (mg)	Density of PO_4 in sap
The 1st period (11.10am. -1.10p.m.)	a	649	0.171	0.24	419	0.052	0.11
	b	621	0.143		359	0.036	
The 2nd period (1.15- 3.15p.m.)	a	860	0.140	0.16	114	0.034	0.31
	b	876	0.143		124	0.041	
The 3rd period (3.20- 5.20p.m.)	a	857	0.197	0.26	52	—	—
	b	714	0.214		112	—	

oxygen circulation. Is this the same with the rice plant which is said to need no aeration ? The test of it was made with regard to phosphorus.

The aeration of washed oxygen and nitrogen gas was made in the circulation vessel mentioned above. During the experiment period of 6 hours a new cut end was made every 2 hours. The results of it are given in Table 5 and 6 and Figure 2.

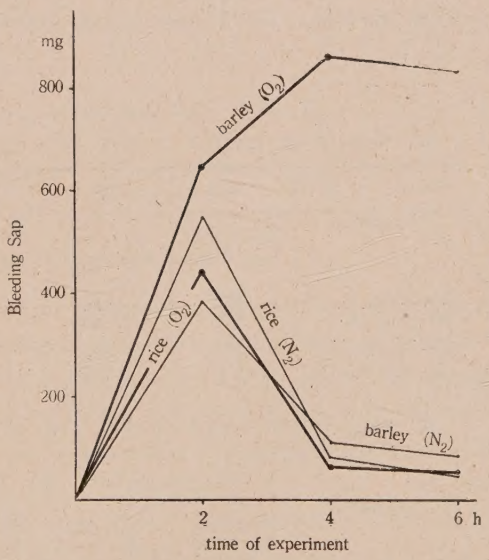

Fig. 2. Relation between Aeration and Bleeding.

These results agree with Lundegardh's[8] results with the barley plant that oxygen circulation has a good effect on bleeding. With the rice plant the difference between the effects of oxygen and nitrogen gas was not clear. In both divisions rice plants showed a trend towards decrease of bleeding sap. This cannot be explained by the reason that the oxygen was sent to the rice plants from the top, for in this case the stems were cut and no oxygen was introduced from the top. But, if so, why did the aeration in the culture solution have no meaning ? And, if oxygen had been sent to the plants, why did the bleeding of the rice plants

shown the same tendency with that of the barley provided with nitrogen gas circulation ? The reason for this cannot be seen.

The aeration made by the circulation vessel necessarily stirs up the culture solutions. So, to examine the effect of the solution being stirred up, an experiment in which no circulation to strip up the solution was made, was conducted (The oxygen contained in the solutions was driven out of it by boiling the solution before it was used and the solutions was kept out of contact with the air by means of liquid paraffin.). The results of the experiment are given in Table 7. According to the table, the results differ according to the experiment days, that is, the roots employed for the experiment. (a) shows that there is no difference in result between both divisions and (b) shows that the division, where oxygen circulation accompaning the stirring up of the solution, gave better results than the othe division. Thus it seems that the effect of aeration which stirs up the solution differs according to a root employed for the experiment. For the purpose of finding the differences of aeration to be caused by different samples of the case of the peculiar reaction of the rice plant to aeration, the relations between the quantity of carbohydrates contained in the roots of rice plants, respirable substrates and its bleeding were examined. The regulation of the quantity of carbohydrate contained by the roots was made by the Hoagland and Broyer's method[6], that is, the quantity of carbohydrates were altered by the concentration of the pre-culture soution. The results of this experiment are given in Table 8 and Figure 3.

Table 7. Relation between aeration, stirring and bleeding.

a) Rice : afterplanted 11 days, July 11, 1951

Treatment	The 1st period		The 2nd period		The 3rd period	
	Bleeding sap (mg)	PO_4 in sap (mg)	Bleeding sap (mg)	PO_4 in sap (mg)	Bleeding sap (mg)	PO_4 in sap (mg)
Aeration (a	305	0.105	144	0.040	80	0.021
Stirring (b	315	0.081	85	0.025	70	0.061
No aeration (a	309	0.102	37	0.008	44	0.005
No stirring (b	314	0.109	37	0.006	25	trace

b) Rice : afterplanted 14 days, July 14, 1951

Treatment	The 1st period		The 2nd period		The 3rd period	
	Bleeding sap (mg)	PO_4 in sap (mg)	Bleeding sap (mg)	PO_4 in sap (mg)	Bleeding sap (mg)	PO_4 in sap (mg)
Aeration (a	296	0.095	91	0.044	57	0.010
Stirring (b	303	0.101	53	0.023	39	trace
No aeration (a	98	0.065	32	0.012	20	trace
No stirring (b	92	0.066	32	trace	25	trace

Notes : Culture solution for bleeding is P_{100}.

Table 8. Relation between sugar contents of root and bleeding.

(a) Aug. 7, 1951

Pre-culture solution	Sugar content of root	Treatment	The 1st period (11.50a.m.–1.50p.m.)		The 2nd period (0.20–2.20p.m.)	
			Bleeding sap (mg)	PO_4 in sap (mg)	Bleeding sap (mg)	PO_4 in sap (mg)
72 hours low conc. (N : 10 mg K_2O : 5 mg CaO : 2 mg MgO : 3 mg) mg/*l*	% 1.20	O_2 circulation a	328	0.128	229	0.056
		O_2 circulation b	343	0.138	280	0.060
	〃	N_2 circulation a	333	0.117	230	0.054
		N_2 circulation b	312	0.118	230	0.060
72 hours high conc. (N : 100 mg K_2O : 50 mg CaO : 20 mg MgO : 30 mg)	% 0.88	O_2 circulation a	364	0.157	332	0.144
		O_2 circulation b	356	0.162	300	0.140
	〃	N_2 circulation a	304	0.156	250	0.109
		N_2 circulation b	302	0.131	251	0.107

(b) July 25, 1951

Pre-culture solution	Sugar content of root	Treatment	The 1st period (10.20–12.20a.m.)		The 2nd period (0.20–2.20p.m.)	
			Bleeding sap (mg)	PO_4 in aap (mg)	Bleeding sap (mg)	PO_4 in sap (mg)
48 hours H_2O	% 1.47	O_2 circulation a	51	0.013	36	0.005
		O_2 circulation b	77	0.014	47	0.006
	〃	N_2 circulation a	92	0.015	38	0.006
		N_2 circulation b	73	0.014	38	0.005
48 hours low conc. (N : 20 mg K_2O : 10 mg CaO : 5 mg MgO : 6 mg) mg/*l*	% 0.97	O_2 circulation a	305	0.105	144	0.040
		O_2 circulation b	315	0.081	85	0.025
	〃	N_2 circulation a	309	0.102	37	0.008
		N_2 circulation b	314	0.109	37	0.003

In Table 8 (a) are given the results of an examination of the effect of aeration upon rice plants the carbohydrate contents of whose roots were made to differ by the pre-cultures with solutions of a low concentration and a high one. According to this the sugar contents in the roots pre-cultured with the solution of a low concentration are 1.20 % and those in the roots pre-cultured with the solutions of a high concentration are 0.88 %. But the effect of aeration is not clear. But the phosphorus content in the latter is greater than those in the former. In Table 8 (b) are given the results of a similar experiment in which the plant was pre-cultured with distilled water — the extreme case of pre-culture. According to this, the sugar contents in the plant pre-cultured with distilled water are 1.47% while those in the plant pre-cultured with the low concentration solution are 0.91%. The bleeding of the former showed a decline. This can be explained as follows.

Bleeding is, as stated in the previous paragraph, connected with the ion in the culture solution employed during the time of experiment, and this connections is, through the process of accumulation of ion from the pre-culture solution, related with bleeding (therefore, carbohydrate contents related with absorption and accumulation is, in this sense, not directly connected with bleeding.).

In other words, ion absorbed by the roots is accumulated to a certain quantity (this includes the organization in the roots), and thereafter make a presence in

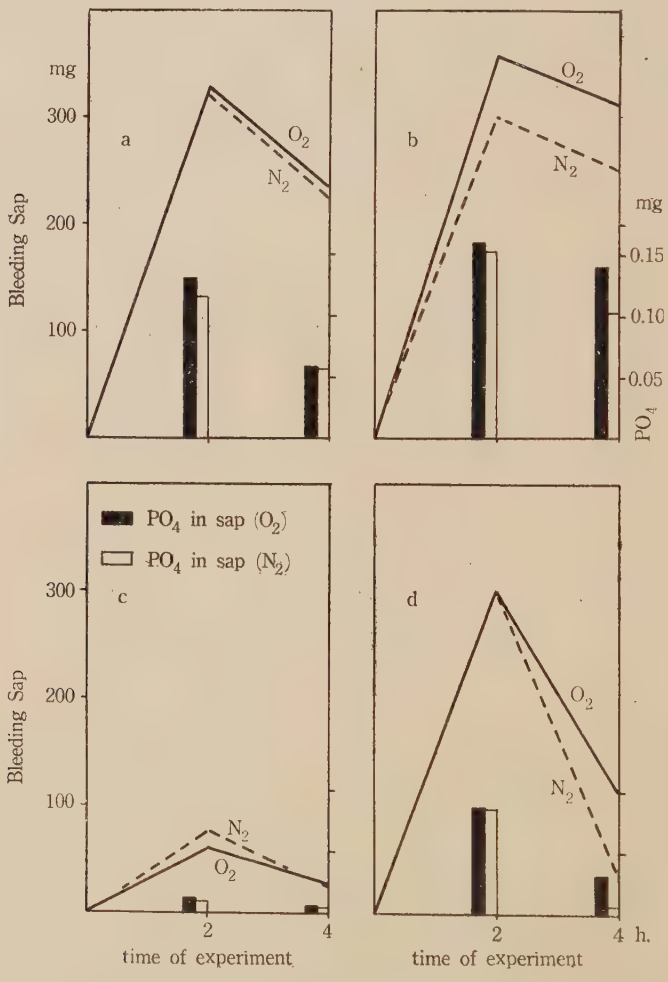

Fig. 3. Relations between sugar contents in root and bleeding.

a : low conc. preculture in Table 8, (a)
b : high conc. preculture in Table 8, (a)
c : H_2O preculture in Table 8, (b)
d : low conc. preculture in Table 8, (b)

bleeding. But the fact that with distilled water as the culture solutions during the time of experiment, bleeding showed a decline, as the above described experiment proved, shown that bleeding is caused by the interactions of inorganic ingredients in the culture solution, the nutrient condition of the roots, and inorganic ingredients in bleeding sap. Though ion is accumulated enough, therefore, in the roots, the transport of ion into bleeding sap is influenced by the constitution of the culture solution. Absorption, accumulation and transport into bleeding sap of ion form each a definite stage, and, if any of them is not carried out satisfactorily, this process does not occur smoothly.

As for this process, with the rice plant pre-cultured with a solution of high concentration, phosphorus contents in the bleeding sap are greater than with that pre-cultured with a solution of low concentration (Table 8 (a)), so that it seems possible for the phosphorus to be transported in some degree by the medium of other accumulated ion. But as is clear from Table 4, (a), (c) the phosphorus is considered to have its own way, that is, from the fact that, unless the plant is directly provided with phosphorus during the time of experiment, the phosphorus in bleeding sap decreases, the phosphorous seems to have its own these successive stages, absorption, accumulation and bleeding.

4. Relations between Bleeding and Respiratory Inhibitor.

As stated above, with rice the effect of aeration was not clear, though this is not the case with barley. In order to observe this phenomenon in relation to the peculiarities of the respiratory system of the rice plant, effects of some respiratory inhibitors upon bleeding were examined. Lundegårdh[9][10] has classified root respiration, in accordance with the degrees of inhibition of KCN, into the anion, the third and the ground respiration. For this experiment were used NaCN which inhibits the cytochrome, chytochrom oxidase system and other

Table 9. Effects of the respiratory inhibitors on the bleeding sap (exp. hr. 2 h).

Treatment		Rice		Barley	
		Bleeding sap (mg)	PO_4 in sap (mg)	Bleeding sap (mg)	PO_4 in sap (mg)
(a) NaCN					
Control	a	335	0.189	203	0.037
	b	322	0.179	227	0.042
0.001 M NaCN	a	110	0.060	72	trace
	b	140	0.081	67	trace
0.005 M NaCN	a	48	0.010	30	—
	b	67	0.017	42	—

(b) CH_2ICOOH

Control	a	176	0.040	494	0.115
	b	140	0.030	400	0.105
0.001 M CH_2ICOOH	a	41	trace	28	—
	b	23	trace	16	—
0.005 M CH_2ICOOH	a	18	—	14	—
	b	15	—	15	—

(c) NaF

Control	a	235	0.030	404	0.069
	b	284	0.033	424	0.073
0.000 M NaF	a	74	0.005	350	0.070
	b	64	0.004	361	0.065
0.010 M NaF	a	42	—	315	0.060
	b	32	—	302	0.058
0.010 M NaF	a			286	0.048
	b			275	0.057
0.020 M NaF	a			208	0.029
	b			227	0.038

Table 10. The relative inhibitors of bleeding by the respiratory inhibitors.

Inhibitor	Concentration of inhibitors				
	Control	1×10^{-3}M	5×10^{-3}M	1×10^{-2}M	2×10^{-2}M
(a) Rice					
NaCN	100(100)	36(37)	16(8)	—	—
NaF	100(100)	26(14)	14(—)	—	—
CH_2ICOOH	100(100)	19(—)	9(—)	—	—
(a) Barley					
NaCN	100(100)	32(—)	16(—)	—	—
NaF	100(100)	85(95)	84(85)	78(73)	64(43)
CH_2ICOOH	100(100)	6(—)	3(—)	—	—

Notes : ( ) indicates rates of phosphorus.

oxidases, and NaF and CH_2ICOOH[4][7][11] — respiratory inhibitors which are related with anaerobic respiration. The resluts of this examination are given in Table 9 and 10.

According to these results NaCN inhibited the bleeding of both rice and barley, but by inhibitors NaF and CH_2ICOOH which are considered to have influence on enzyme which is connected with the process of anaerobic respiration, the former exercised a greater influence upon rice than upon barley. This is considered,

taking into account the results of aeration mentioned above, as evidence for the theory that the rice plant developed anaerobic respiratory system as Taylor[13] has suggested.

As for the phosphorus, it decreases parallel to the inhibition of bleeding, that is, the phosphorus in bleeding was decraesed by both NaCN and CH_2ICOOH but its inhibition by NaF occurred only in the rice plant. The relations between the phosphorus in bleeding sap and respiratory inhibitors which anticipitate the accumulation of phosphorus, is not known yet to be direct or indirect, and is to be decided in the future.

III. Summary

In the previous papers, the authors studied physiological functions of phosphorus and iron in order to elucidate the special characters of those elements on the absorption by the rice plant. In the present paper, we studies effect of aeration and respiratory inhibitors on the phosphorus in bleeding sap which are considered to have relations with the absorption mechanism in the rice plant. The seedlings of rice and barley were used in the bleeding experiments.

The results of the investigations are summarized as follows,

(1) Phosphorus contents of bleeding sap were generally larger in rice than in barley.

(2) In experiment with plants which had been exposed for several days to distilled water, exudation of bleeding sap decreased. When experiment solutions were distilled water, it also decreased regardless the prehistory of plants.

(3) There was a close connection between phosphorous in bleeding sap and phosphorus in culture solutions during the time of experiment (0–2 hours).

(4) During experiment periods the bleeding proceeded at normal speed by the aeration of solution in barley, but it fell in rice regardless of the aeration.

(5) The bleeding were inhibited by NaCN, CH_2ICOOH, in both plants, but its inhibition by NaF was more sensitive in rice than in barley. Inhibitions of phosphorus in bleeding sap occurred in the same manner.

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On the Effect of Environmental Conditions on the Tuberization of the Potato Plant*

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The rational growing of a crop can be effected by the discovery of the environments suitable to the crop. It is a matter of great importance to the theoretical explanation of a crop growing that we should make clear what conditions the rational growing environments have, and why they are suitable to the crop. These conditions vary not only with the kinds of crop, but also with the season or objects. From a practical point of view, therefore, it is necessary for us to consider, first those points common to crops in general, and then study the growing environments particular to individual crops.

Now we can suppose many elements for the growing environments, but those which have hitherto been studied chiefly, are temperature, soil humidity, soil temperature, soil aeration, soil structure, etc. A great many reports have been made on the potato plant. We have no time here to study all of them in full, but now we shall make a general survey of them. First, on atomospheric temperature and underground temperature, Emerson (1914), Smith[19] (1915), Bushnel[5][6] (1923, 25), Tanaka (1937), Teshima and Takahashi (1926) made their studies public; second, on soil moisture, Johnson and Boyle (1920), Werner[22] (1926), and Hadenburg[11] (1926) wrote their papers, and third, on the length of daylight time, or on its length in relation with temperature, Garner and Allard[9] (1923), Doroshenko[8] (1930), Rozumov[16] (1931), Beamont and Weaver[3] (1921), Robert and Struckmeuer[17] (1938), Stelzer and Torka[21] (1940) made their reports. On soil aeration, Noguchi[15] (1944) introduced the studies by Kopecky which were made as early as 1914 and by Sugawara later. We can find few reports on the results of a minute observation of tuberization resulting from the difference of soil structure as a physical condition of soil, but three years ago Yamamoto and

* The 75th report of the Institute for Agricultural Research, Tohoku University (1952).

Oizumi[25] (1949) made their experiments and reports on them.

On the relation of the acidity of soil as an environmental condition in a broad sense to the growth of the potato plant and its tuberization, Smith (1932) made his report.

From those studies, we can see the outline of the growing environments of the potato plant, but this problem usually depends upon the synthetic effects of many elements, and individual reports sometimes vary according to their equipments, methods etc. Moreover, they cannot be said all to be satisfactory scientifically. In view of this, with the object of making clear the theory of potato growing, the present writers observed through what processes, tubers are formed[25] (1949) and reported the results. As the conclusion we observed that the charactor of stolons to elongate and begin to swell at their tips and the process of small tubers which are formed at the tips of the stolons to grow vigorously, differ essentially from each other. Thinking that the analysis and study of the environmental elements of tuberization based on the above observation, would add a new light to the studies and results which have hitherto been made, we have made our experiments since 1946. We are not satisfied with our result, and needless to say, many things must depend upon further studies. But now that we have completed our studies in outline, we should like to submit them to the criticism of fellow-students.

The experiments in this report were made at the Institute For Agricultural Research, Tohoku University, from 1946 to 1951. Although all the chapters cannot be said to be a sequence, they may be grouped as environmental elements, so we collected them into the head subject.

1. Effects of the high-temperature environmental condition on tuberization

1. Forward

The potato plant is naturally best adapted to cool districts. To make tuberization better, it is considered that we had better avoid the mid-summer when underground temperature is highest. On the regional relation between temperature and tuber products, Smith[19] (1915) and Daigo (1945) made their reports.

But about why low temperature is suitable, while high one is not, and what morphological difference is caused by the change of temperature, few have reported in full. In this chapter, we observed how the high-temperature (underground as well as atmospheric) environmental condition will affect the growth of stolons and tubers, from the point of view of their growth period . The observation was made from April to July, 1946.

2. Materials and methods

The variety we used was *Danshaku*, produced in Hokkaido the previous year. With a uniform size weighing about 30g., each seed was cut into two and germinated. Each sprout was planted in a Wagner's pot (1/20,000). The fertilizer applied to each pot was 3 *momme*, consisting of ammonium sulphate, superphosphates and potassium chlorate with the ratio of 1 : 1 : 0.5. No fertilizer was supplementarily added, and after germination, mulching was done once.

As environmental conditions, the open air and a green house were taken up. The plants grown in the open air were tranplanted in the green house at three periods; observations were made on how the high temperature after the translocation will affect those plants.

The experiment regions were 4 as follows:

A. A region in the open air throughout the growth period.
B. One translocated soon after the germination on May 4.
C. One translocated when tuberization began.
D. One translocated when tuberization had been almost completed.

As to the temperature in the open air and the green house, the maximum was 24–30°C, the minimum 8–14°C, the tempreature at 10 A. M. 20–23 C in the former, while in the latter the maximum 31–37°C, the minimum 13–17°C and the temperature at 10 A. M. 25–28°C.

3. Results

(i) First examination

The object of this examination is to see how the potato plant will be influenced during the changing period from stolon growth to tuber formation, when it has been put under the high-tempreature condition since the early growth period. Therefore, on June 4 when tuber are supposed to form in the ordinary

Table 1. Effects of the high-temperature condition on the early growth of top parts.

Region		No. of plants examined	Average height of individuals cm.	Average top weight of individuals g.	Leaf weight of individuals g.	Top weight / height	Leaf weight / top weight
Open air	A	8	15.1	36.3	19.5	2.40	0.54
Green house	B	5	15.8	24.0	14.3	1.52	0.59

open air, the plants dug up for the first time and examined. The comparison of the growth conditions of top between the two regions is as seen in Table 1.

The plants in the green house region are greater in height, while those in the open air are superior in top weight and leaf weight. The ratio of top weight to height is quite clearly greater in those in the same region, which shows that in the green house, the plant has grown too high for its growth of tops ; in other words, the growth of tops is insufficient for its height. Seen as a whole, we can say that it has begun to show the waste sprout condition. In the ratio of leaf weight to top weight, there is no great difference between the two regions ; in this ratio, the green house region is rather superior.

In and after the second experiment of ours and in those of the Agricultural Experiment Station of Chugoku and Shikoku,[7] the high-temperature region is lower in this ratio. But since the present result are about the effects on the early growth, any striking difference of this ratio between the two regions caused by the high-temperature condition has not yet appeared, we suppose.

Table 2. Effects of the high-temperature condition at the early stage of growth on the development of stolons and tuber formation.

Region	Average No. of Stolons per individual	Average of longest stolons in individual	Average No. of tubers per individual	No. and percentage of various stolons classified according to the from at the extremity*					Total No. of stolons
				I	II	III	IV	V	
A	4.38	cm. 2.10	2.62	0	0	3	11	21	35
				%		8.6	31.4	60.0	100.0
B	5.20	4.10	0.20	11	8	3	3	1	26
				% 42.3	30.8	11.5	11.5	3.8	100.0

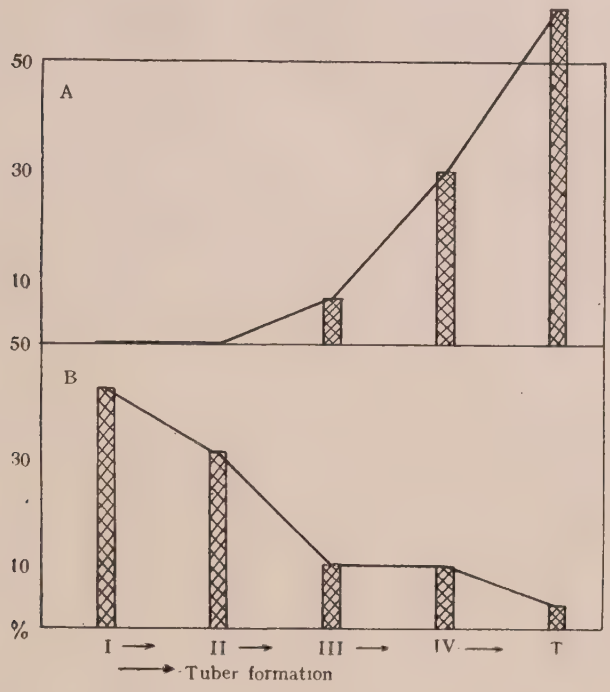
Next we shall see has the high-temperature treatment from the early stage of growth will affect the growth under ground.

The results are shown by Table 2.

Region A is slightly greater in the number of stolons, while Region B is clealy superior in the average length of the longest stolons. This region also is superior both in the number and quantity of stolons. This tells the change into accumulation growth is delayed in this region. This will be clearer if we look at the number of tubers and tuber formation. The progress of tuber formation is shown by Figure 1.

(ii) Second examination

The object of this examination was to see what will become of the potato plant



A ; Open air regin. B ; High-temterature region.

Fig. 1. Effects of the high-teperature condition on tuber formation.

at its swelling period, when it has been placed under high-tempreature since the early stage of growth and how it will change during its later swelling process, if its tuber formation has been normal and it has been put under high temperature since the early swelling period. The plants were dug on June 25 and examined.

The results of the examination of tops are seen by Table 3.

Table 3. Effects of the high-temperature condition since the early stages of the growth and tuberization on the growth of the tops.

Region	No. of plants examined	Average height of individual cm.	Average top weight of individual g.	Average leaf weight of individual g.	Top weight / height	Leaf weight / top weight
Open air (A)	4	95.0	227	139	2.39	0.61
High-temperature since May 4 (B)	5	123.0	275	134	2.23	0.49
High-temperature since June 10 (C)	5	89.5	202	112	2.27	0.55

Region B is decidedly superior in height. Region A is somewhat superior to Region C, but the difference may not be essential, considering variations in each region. The top weight is in the order of B, A and C, while the leaf weight in the order of A, B and C, Next the ratio of top weight to height is in the order of A, C and B, that is, the longer a plant is in the high temperature condition, the smaller the ratio becomes, which shows that the high-temperature condition does not so greatly help tops grow as it does the plant grow in height. In reality, in the high-temperture region, the top growth is remarkable, but axillary buds do not develop well. The ratio of leaf weight to top weight is also in the same order ; the longer plants are in the high-temperature condition, the worse the leaf

Table 4. Effects of high-temperature condition from the early stages of growth and tuberization on the development of stolons and tubers of uuderground parts.

(I) Development condition of stolons and tubers.

Region	Average	Number of stolons in individual			Average length of longest stolons in individual cm.	Average No. of tubers of individual	Average tuber weight in a plant g.
	Total stolons	Primary stolons (1)	Secondary stolons (2)	Second stolons (3)			
A	8.50	6.5	0.5	1.5	9.3	3.25	85.0
B	13.00	5.6	6.6	0.8	37.8	0.60	12.0
C	8.00	7.0	0.4	0.6	10.5	3.60	48.3

(1) Stolons considered to have primarily shooted out from the main stem under ground.

(2) Stolons considered to have secondarily shooted out from the main stem under ground.

(3) Stolons produced half-way primary stolons.

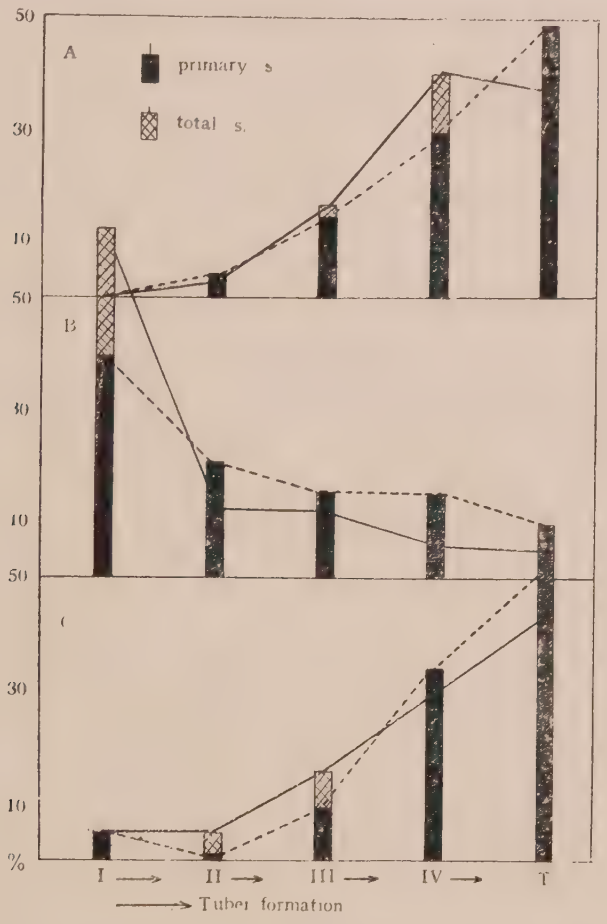
(II) Condition of tuberization.

Region	Total Stolons						Primaly Stolons					
	No. and percentage of stolons according to the shapes of their tips					Total No. of Stolons	No. and percentage of stolons according to the shapes of their tips					Total No. of stolons
	I	II	III	IV	V		I	II	III	IV	V	
A	0	1	6	14	13	34	0	1	4	8	13	26
	%						%					
		2.9	17.7	41.2	38.2	100.0		3.8	15.4	30.8	50.0	100.0
B	42	8	8	4	3	65	11	6	4	4	3	28
	%						%					
	64.6	12.3	12.3	6.2	4.6	100.0	39.3	21.4	14.3	14.3	10.7	100.0
C	2	2	6	12	18	40	2	0	3	12	18	35
	%						%					
	5.0	5.0	1.50	30.0	45.0	100.0	5.7		8.6	34.3	51.4	100.0

development becomes in quantity and seen the smaller the breadth of leaves is.

The underground development conditions are seen in Table 4.

The number of stolons, there is no essential difference between A and C, while B is much greater is it than the rest. Now let us observe those stolons, classifying into three kinds of primary, secondary and "second" ones. From the fact that B has a great many secondary stolons, it will be seen that the high-temperature condition since the early stage of growth, causes to grow many stolons generally, because secondary stolons have sprouted successively. And the reason there is little difference between A and C will be that the latter has been under high-



A ; Open air region. B ; High-temperature region since the early stage of growth. C ; High-temperature region since the commencement of tuberization.

Fig. 2. Effects of high-temperature conditions on tuber formation.

temperature from the early stage of tuberization, the time when tuber formation was already completed, and that consequently the high-temperature little affected the growth of stolons immediately.

In the length of stolons as well, Region B is greater than the other two.

In short, those plants which have been put under the high-temperature condition, are vigorous only in the vegetative growth of stolons, both in number and quantity.

The number of tubers is far smaller in Region B, because the high-tempreature condition prevents tuber formation, only fostering the nutritive growth of stolons. No essential difference between the other two regions is probably caused by the fact that the time to have begun the high-temperature treatment in Region C fell on the early stage of tuberization when the nuber of tubers has almost been decided, because tuber formation was already completed. Thus during such a short period as 15 days from June 10 to June 25, any later action cannot affect the number of tubers.

On the other hand, the average tuber weight of an individual stands in the order of A, C and B — the longer the high-temperature condition lasts, the smaller the weight is.

In other words high-temperature has an immediate effect on tuber development.

Now the condition of tuber formation is to be seen by Table 4 (II) and Fig. 2. As they tell us, Region B is decidely inferior both in total stolons and primary ones. There is no definite difference between A and C again.

(iii) Third examination

The last examination was made on July 20, the harvest season, when tops have almost withered, and observations were made on how the high-tempreature

Table 5. Effects of high-temperature condition on the development of stolons and tubers of underground parts, since the early stage of growth, or the earliest or last stage of tuberization.

(I) The development conditions of stolons and tubers.

Region	Average number of stolons of individual				Average length of the longest stolons in individual	Averge No. of tuber in individual	Averge tuber weight of individual
	Total stolons	Primary stolons (1)	Secondary stolons (2)	Second stolons (3)			
					cm.		g.
A	5.20	5.2	0	0	9.7	4.4	215.0
B	7.40	5.8	1.6	0	32.5	0.2	5.0
C	6.80	6.0	0.4	0.4	42.4	2.4	42.0
D	5.80	5.8	0	0	13.4	4.6	155.0

(1) (2) (3) of. Table 4 (1).

(II) Conditions of tuber formation.

Region	Total Stolons					Total No. of stolons	Primary stolons					Total No. of stolons
	No. and percentage of stolons according to the shapes of their tips						No. and percentage of stolons according to the shapes of their tips					
	I	II	III	IV	V		I	II	III	IV	V	
A	0	0	1	3	22	26	0	0	1	3	22	26
	%		3.9	11.5	84.6	100.0	%		3.9	11.5	84.6	100.0
B	0	25	6	5	1	37	0	17	6	5	1	29
	%	67.6	16.2	13.5	2.7	100.0	%	58.6	20.7	17.2	3.5	100.0
C	0	0	12	10	12	34	0	0	8	10	12	30
	%		35.3	29.4	35.3	100.0	%		26.7	33.3	40.0	100.0
D	0	0	0	6	23	29	0	0	0	6	23	29
	%			20.7	79.3	100.0	%			20.7	79.3	100.0

treatment will influence on the last harvest, since the early stage of growth, or the earliest or last stage of tuberization.

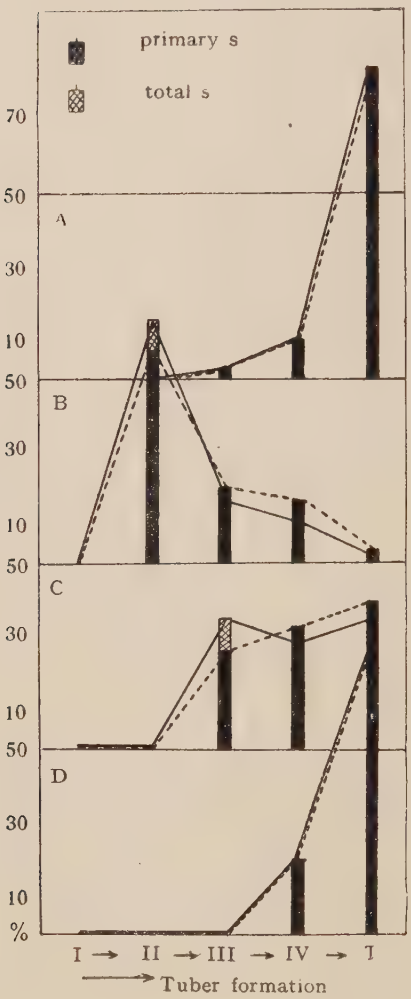
The experiment was made only on underground parts, as both stalks and leaves above ground had almost been dead.

Table 5 shows its results. The number of tubers examined is five in each region.

The number of stolons is in the order of B, C, D and A ; the longer they are in the high-temperature condition, the greater their number is. There was, it is considered condition, no essential difference between A and C in the second examination, but in this examination, a definite deffernece is seen between them. The number of stolons is especially great in Region B and C — this is chiefly because the number of stolons other than primary ones is great in these regions, just as we have seen in the last examination. In the length of stolons as well, Region B is especially remarkable, which is followed by C, D and A successively. In the last examination, we have seen that when the period of the high-temperature treatment is short, its influence on the length and number of stolons is little ; the present examination also shows that between Region D, a high-temperature region since July 5, and A, there is very little difference in those points, expecially in their number hardly any difference.

Next the number of tubers under ground is greatest in A and D, which are followed by C and B. Between the first two region, there is no difference. The effects of this treatment is cleary visible in Region C, at this period.

It can be clearly recognized in the comparison of A with D that the high-temperature condition exerts no immediate effects on the change of the number of tubers, as we have seen in the second examination. But the average weight of tubers, index of tuberization, becomes light with the length of the period of this treatment. — in the order of A, D, C and B. We see here again that this condition is injurious to tuberization and that its effects appear immediately after this treatment.



A ; Open air regin. B ; High-temperature region since the early stage of growth. C ; High-temperature region since the commencement of tuberization. D ; High-temperature region since the last stage of tuberization.

Fig. 3. Effects of high-temperature condition on tuber formation.

The conditions of tuber formation are same as seen in the second examinations. In Region D where the period of this treatment is short, its effects are hardly to be seen, but in C, a little and in D most remarkably. In short, the longer this treatment lasts, the more tuber formation is delayed.

(iv) Summary of the foregoing three examinations

In summarizing the results of the foregoing three examinations from the aspect of the growing process of potato plants, we want to examine how the high-temperature treatment will operate on the development of stolons and tubers.

First, taking all the kinds of stolons into consideration, their number is greatest in Region B (treated since the early stage of growth), its highest value seen on June 25, but on July 20 when the last examination was made, it was much reduced with little difference from the rest the regions. Now, the increase of stolons in this region being caused by the sprout of unavailable secondary ones, the disappearance

of such stolons at the last stage of growth lessens the disparity in their number among the regions.

The above mentioned conditions are to be seen by Figs. 4 and 5. In Fig. 5, so far as primary stolons are concerned, there can be seen little difference among the regions.

Second, the number of tubers is apparently small in B, a high-temperature treatment region since the early stage of growth. Region C treated since the commencement of tuberization does not differ from A till June 25 after the treatment, but on July 20, difference is cleary visible, and in Region D as well, little difference is to be seen till July 20. If the high-temperature treatment is prolonged, and the plant should never wither, there will appear some difference between A and D, as between A and C, (See Fig. 6)

The change in tuber weight, namely the degree of tuberization is plainly less than in the open air region at the examination soon after the hightemperature

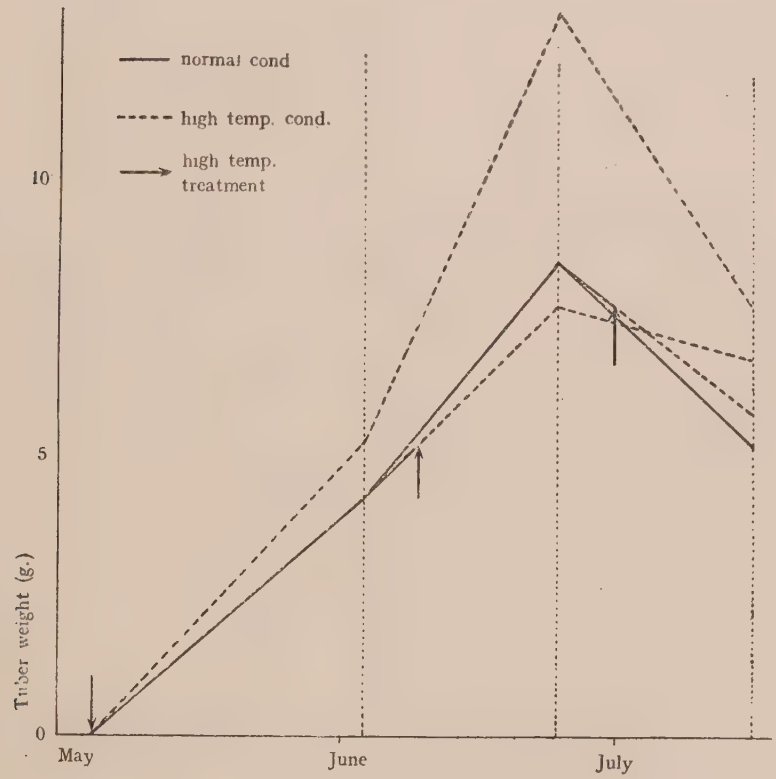


Fig. 4. Change in the total number of stolons owing to the high-temperature treatment.

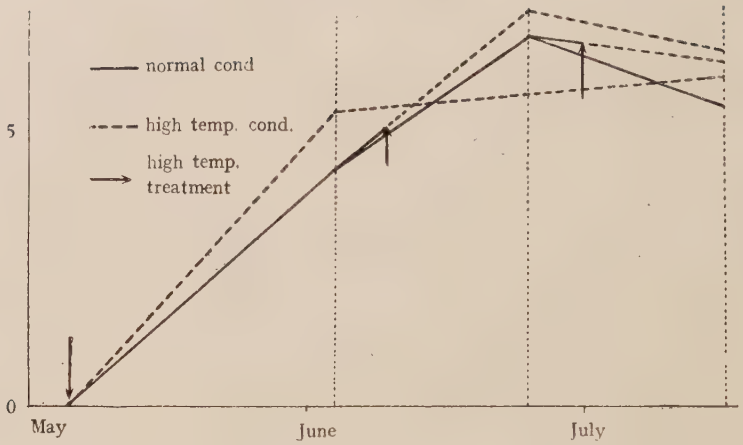


Fig. 5. Change in the number of primary stolons due to high-temperature treatment.

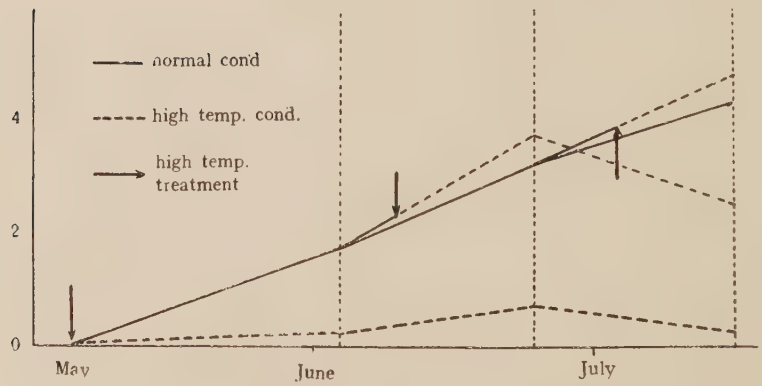


Fig. 6. Change in the number of tubers due to the high-temperaure treatment.

treatment. It is to be seen by Fig. 7 that high-temperature directly prevents the accumulation growth.

4. Conclusion

When a potato plant is grown under the high-temperature condition, the growth of the plant above ground is inferior, against the vigorous extention of its height. To consider its tops only, the development of its leaves decreases in comparison with that in the open air region. In other words, the ratio of

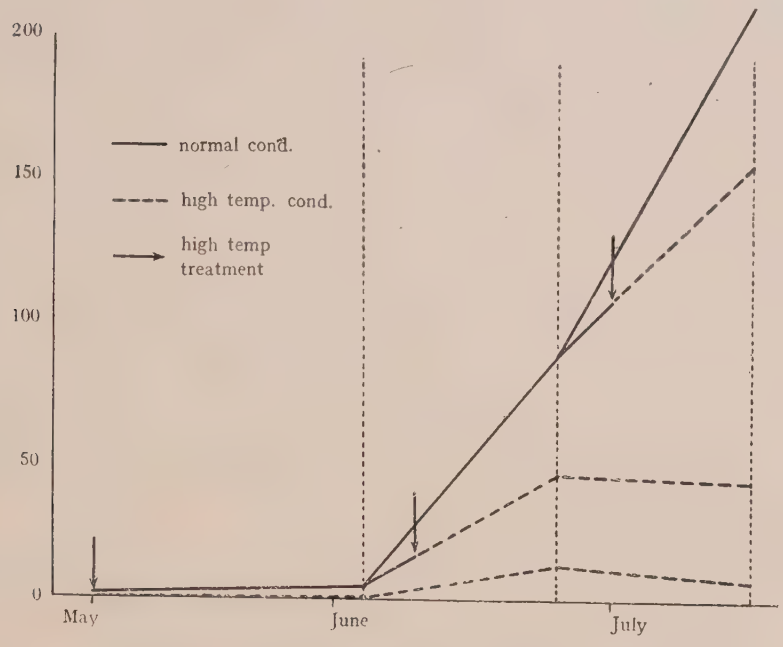


Fig. 7. Effects of the high-temperaure treatment on tuberization.

top weight to height and that of leaf weight to top weight are less than those in the open air region — the plant is liable to be subject to "waste sprout". This phenomenon appears greatly, as high-temperature lasts long. The decrease of the ratio of leaf weight to tuber weight was also observed by the Agricul tural Experiment Station of Chugoku and Shikoku*.

What about the effect of the high-temperature condition on the development of stolons of underground part ? If a plant is placed under high-temperaure since the early stage of growth, stolons conditinue to elongate perpetually and tuber formation is delayed. Besides, secondary stolons and second axillary ones sprout, increasing the number of stolons as a whole. The high-temperature treatment since the commencement of tuberization after the completion of tuber formation exerts no remarkable influence, if the period is short, while as the period become longer, stolons other than primary ones sprout more or less. Needless to say, this influence of high-temperature on stolons is related to its effects on the development of tubers.

The effects of high-temperature on tuberization are to be seen immediately. It prevents tuberization, and reduces it greatly or almost to nothing. As to the shapes of tubers, smaller ones become zigzag-shaped, growing thick, and big ones sometimes sprout again, as the natural result of physiologic unbalance due to

high-temperature. Such being the case, we shall find out that the opinion of Bushnel[6] (1925) and of Beamont and Weaver[3] (1931) that the unbalance of assimilation and respiration in the leaf parts prevents the accumulation growth to undergrounds parts is sufficiently convincing.

The phenomenon that a tuber once formed sprouts again was explained by the observation of Teshima and Takahashi (1949) that high-temperature causes the secondary growth of a potato plant. Their observation is to be understood in the same light with the present experiment.

Next we shall consider the effects of high-temperature on the number of tubers. It is quite natural their number is extremely small, because tuber formation is delayed by the high-temperature treatment since the early stage of growth. The same treatment after the commencement of tuberization has no immediate effects on the number of tubers, but if its period becomes longer, their number decreases, owing to the reduction of small tuber to stolon-shaped ones, as we have described above.

In short, we shall find that the high-temperature condition is undesirable to the yield of the potato plant, but as to the temperature limit, scholars are divided in opinion. According to Bushnel[5] (1932), 15°C–18°C is suitable to the growth of the plant and any temperature higher than 29°C stops the growth entirely, while Robert and Struckmeyer[17] (1937) state that in the temperature as high as 70° F (in long daylength period) we can see no yield of the plant. Probably the temperature of 25°–28°C, or at least, any higher than 25°C (at 10 in morning) in the green house of the present experiment is undesirable, we think.

In the relation of carbon acid assimilation to temperature, 20°C shows the maximum, 10°C and 30°C reduce it to half, while at 40°C, the operation is entirely stopped.

II. Effects of relative degrees of atmospheric and underground temperature on tuberization

1. Forward

The object of growth the potato plant is the yield of tubers of underground parts. It is considered that soil temperature in underground parts has not only a relation to the metabolic physiology of the root, but an important meaning to the changing mechanism of assimilation products to tubers underground. Therefore, Emerson (1914), Werner[22] (1935), Tanaka (1937) have hitherto reported about the importance of underground temperature to the potato plant. It is generally believed relatively low underground temperature is desirable to the yield of tubers of the plant.

With those crops whose object is the yield of storing organs under ground, underground temperature has an important meaning, as Ito (1947), Nishiuchi[14] (1947) reported on sweet potatoes. Especially the latter's view is quite interesting to us, because he has arranged underground temperature as a ruling factor of tuberization in sweet potatoes in the theory that temperature system is effective.

Now in this experiment, we observed underground temperature separately from atmospheric temperature and tried to see how tuberization is affected by their relative degrees.

2. Materials and Methods.

The variety we used is *Danshaku*. Picking those seeds with uniform size of about 10g., we put them into a germinating bed on April 5, and made them sprout. When sprout grew to be 1 cm. in height, we took them out of the bed and planted each sprout to a Wagner's bed (1/20,000) as one sprout respectively.

As experiment regions, we arranged out-of-door and green-house ones. For underground temperature conditions, we considered the three kinds of regions- a region where city water is left as it runs around the pot, the one where the pot is left as is on the ground and the one under ground where the pot is buried. Out of these, we formed the follwing five regions.

Table 6. Explanation of treatment experiment regions

Experiment region	Place of putting pots	Treatment of pots	Expected condition of temperature		
			Atmospheric temperature	Underground temperature	Range
A	Open air	Left as it is on the ground	Low	High	Much
B	do	Buried under ground	Low	Medium	Medium
C	do	City water is left as it runs around the pot	Low	Low	Small
D	Green house with open windows	Left as it is on the ground	High	Maximum	Most
E	do	City water is left as it runs around the pot	High	Low	Small

In treating pots in Regions C and E, we put them in a concrete water tunk and let city water as it flows in it.

The number of pots used in this experiment is 5 in each region, and the treatment was begun on May 10, immediately after germination.

The plants were dug on June 28 at the same time, when top growth was at its height, and morphological observations were made on tops and underground parts.

Besides the observation of plants, we measured not only atmospheric and underground temperature, but also soil moisture, as a means of quantitative endorsement of the difference in environmental conditions. The chief object of this observation is to realize the difference of temperature conditions, but we examined humidity, too, because we cannot think of underground temperature, independent of soil moisture, and besides, the equipments being so poor, it will be necessary for us to take the difference in moisture into consideration.

3. Results.

(i) Temperature and soil moisture in the Experiment Regions.

Before proceedings to the main issue of the results, we shall state the results of our measurement of environmental conditions in each region.

(a) Atmospheric temperature.

We measured atmospheric temperature in the open air and greenhouse six times both by a thermometer (every three hours) and a self-registering ther-

Table 7. Conparison of atmospheric temperature between the open air and green house regions.

Date	Weather	Open air				Green house			
		Maximum	Minimum	10A. M.	Range	Maximum	Minimum	10A. M.	Range
May 11	Fine	30.0°C	11.5	23.5	18.5	34.5	13.8	27.0	20.2
〃 26	Fine	24.7	9.5	21.5	15.2	32.5	12.7	26.0	19.8
June 13	Fine, cloudy a while	26.0	16.5	21.7	9.5	32.5	18.0	28.0	14.5
〃 23	Rainy, fine a while	24.8	14.0	22.0	10.8	31.0	17.5	25.5	14.5
〃 25	cloudy and rainy	—	—	—	—	32.0	15.0	27.0	17.0
〃 29	Fine	28.0	14.3	23.0	13.7	32.0	17.0	26.0	15.0

N.B. : Average value of three thermometers.

Table 8. Comparison of underground temperature

Date	Region A				Region B			
	Maximum	Minimum	10A. M.	Range	Maximum	Minimum	10A. M.	Range
May 11	27.2°C	13.0	23.7	14.3	22.4	13.7	19.0	8.7
〃 26	24.6	11.5	22.5	13.1	21.5	15.1	18 5	6.4
June 13	23.5	16.1	21.5	7.4	19.3	17.7	17.0	1.7
〃 23	21.5	14.5	—	7.0	21.0	16.0	—	5.0
〃 25	19.5	15.0	—	4.5	18.0	15 0	—	3.0
〃 29	25.0	11 5	18.8	13.5	25.0	13.0	17.5	12.0

mometer. Table 7 shows the maximum and minimum temperature, that at 10 A. M. and the difference between the maximum and minimum, namely range. This table tells us that the temperature in the greenhouse is in average 3–4°C higher than that in the open air and in range 3–5°C higher.

(b) Underground temperature.

The underground temperature was taken six times as in (a) by a thermometer in each region, at 10 cm. underground and about 5 cm. from the periphery of a pot. Table 8. shows its results.

To sum up, the maximum temperature is highest in Region D, next comes A and B, and C and E are lowest in it. There is no essential difference between the last two.

In the minimum, there is very little difference among the regions. If I venture to give any difference, Regions C and E are lower in it than the rest. The tempreature at 10 O'clock in the morning is in the order of D, A, C and E (C and E have almost the same). In range, D>A>B>C, E.

The above-described atmospheric and underground temperature agrees completely with expected conditions, in relative relationship.

(c). Soil moisture

Between the open air and greenhouse, the wind and other delicate weather conditions as well as temperature differ, so does the transpiration from the surface of the earth.

And in Regions C and E where city water is left as it flows, the botton of a pot must be plugged, which is another factor to make it difficult for soil moisture to be uniform.

Therefore, we tried to keep proper moisture by sprinkling water morning and evening, to lessen the difference of soil moisture as little as possible. During the present experiments, we measured soil moisture in each treatment region four times. Its results are shown by Table 9.

On the whole, moisture is a little lower in the green-house than in the open air. Though not evident mathematically, transpiration very much in the green-

among all the Regions.

Region C				Region D				Region E			
Maximum	Minimum	10A. M.	Range	Maximum	Minimum	10A. M.	Range	Maximum	Minimum	10A. M.	Range
18.5	12.3	16.5	6.2	32.2	17.0	27.0	13.3	18.5	12.9	16.5	5.7
19.3	13.3	17.2	6.0	27.7	15.4	22.5	12.3	18.4	14.1	17.0	4.3
19.7	15.4	17.2	4.3	28.5	18.8	23.0	9.7	19.7	16.2	18.0	3.5
19.3	15.0	—	4.0	26.0	15.0	—	11.0	19.5	15.0	—	4.5
17.0	15.0	—	2.0	19.8	14.5	—	5.3	17.6	16.5	—	1.0
20.0	14.5	16.5	5.5	23.0	11.0	25.0	22.0	21.5	15.0	19.0	6.5

Table 9. Condition of soil moisture.

Date	Time	Weather	A	B	C	D	E
May 12	7 A. M.	Fine	48 4	49.1	45.6	44.2	42.2
June 8	5 P. M.	Cloudy	44.0	36.2	38.2	36.4	36 2
〃 22	5 P. M.	Fine	47.1	55.1	41 1	48.9	41.3
〃 28	5 P. M.	Fine	51.1	56.7	58.7	47.8	42.0

house region, so that much water had to be sprinkled morning and evening, which tell the range in soil moisture, change to day according is greater in this region.

(ii) Growth of tops

Plants were dug on June 28 and observed. Table 10 shows the results of the observation on tops, in average value.

Table 10. Comparison of the growth of tops.

Region	Height cm.	Top weight g.	Leaf weight g.	Top weight / Height	Leaf weight / Top weight
A	39.0	191.0	107.6	4.90	0.56
B	45.0	237.0	126.4	5.27	0.53
C	36.6	153.0	69.4	4.18	0.45
D	51.4	136.0	59.6	2.65	0.44
E	54.2	121.6	50.6	2.24	0 42

N.B. : Five plants observed in each region.

In the height, Region D and E are clearly superior to the other three, while among the rest, it is in the order of B, A and C.

Both top weight and leaf weight are in the order of B, A, C and E. Now in order to see the degree of the development of tops in comparison with the height elongation, let us observe the ratio of top weight to height. This ratio is greatest in Region B and is in the order of A, C, D and E. It is especially small in the green-house region, because plants are subject to waste sprout owing to the high-temperature in it, while the development of lateral sprouts is bad, thus the tops in general develops bad.

The ratio of leaf weight to top weight is in the order of A, B, C, D and E. In green-house regions and running water ones in the open air, it is less than 0.4, while in A and B, more than 0.5. According to the naked-eye observation, Regions A and B show normal growth conditions in general, while Regions D and E begin to show abnormal growth already in the green-house with high-temperature, and in Region C, probably because of too low soil moisture, the plant in gene-

ral becomes stunted and leaves harden and are liable to break-such an unhealthy condition was probably brought about by the fact that the absorption process from roots is not normal. Thus the ratio of leaf weight to top weight may serve to draw a line of demarcation between normal and abnormal conditions to some extent. But this problem needs further investigation.

(iv) Development of stolons and tubers in the underground parts

The development conditions of stolons and tubers in the underground parts are as seen in Table 11.

Table 11. Development conditions of stolons and tubers in the underground parts.

Region	Number of available stolons	Number of unavailable stolons	Length of the longest stolons in individual cm.	Root weight g.	Tuber weight g.	No. of tubers	Average tuber weight per piece g.	Tuber weight / Top weight	Tuber weight / Leaf weight
A	4.4	10.8	4.2	9.4	262.2	5.0	52.4	1.37	2.44
B	3.8	7.4	6.8	8.0	343.0	4.2	81.7	1.45	2.73
C	4.0	12.6	4.6	10.8	146.4	4.6	31.8	0.95	2.11
D	3.4	9.8	5.2	10.0	73.6	3.4	21.6	0.54	1.23
E	2.8	9.6	6.2	7.8	66.2	2.8	23.6	0.54	1.29

N.B.: Average of five plants.

In the number of available stolons, A>C>B>D>E, but when we consider variants in each region, we cannot always think that there is some qualitative difference among those regions. And those stolons have all the same tendency, only the more or less development of axillary tubers* causes them to differ a little in absolute value.

In Region B, the number of unavailable stolons is smallest, quite contrary to the fact that both tuber weight and average weight per piece are greatest in this region. From this we can imagine that much development of unavailable stolons is an undeasirable phenomenon to the yield of tubers. With the number of tubrs, there is no specially striking difference, but on the whole, the greenhouse regions are inferior.

The average tuber weight individuals is heaviest in Region B and is in the order of A, C, D and E, between the last two, there may be no essential difference.

Next the ratio of tuber weight to top weight, or to leaf weight is clearly greatest in Region B and among the rest, A>C>D, E.

* See fig. 8.

(v) Dispersion of tubers according to their size

As we have already seen, the number of tubers is not always related to tuber weight, therefore the size of individual tubers differ one another. Now we shall compare tubers in each region, from their dispersion according to their size.

Table 12 shows their dispersion among the graded sections, each with a difference of 20 g. from the next.

Table 12. Dispersion of tubers according to their size.

Region	Up to 10 g.	Up to 30 g.	Up to 50 g.	Up to 70 g.	Up to 90 g.	Up to 110 g.	Up to 130 g.	Upward	Total number of tubers
A	5	6	5	5	2	2			25
B	4	0	3	3	1	3	3	4	21
C	7	2	11	1	2				23
D	4	8	5						17
F	3	7	4						14

It is clear that in a region where the average tuber weight per individual is heavy, so many big tubers are to be got. In other words, much yield does not necessary imply that the number is great. It is rather important to make those tubers formed from the first primary stolon as big as possible.

(vi) Specific gravity of tubers

We have now seen the results of observation on tops and underground parts, in relation to the yield. Measuring the specific gravity of tubers, we shall observe if there is exerted any influence on the quality of tubers, by the fact that the plants have grown under planned treatment conditions.

Table 13. Comparison of the specific gravity of tubers.

	A		B		C		D		E	
	Tuber weight	Specific gravity	Tuber weight	Specific gravity	Tuber weight	Specific gravity	Tuber weight	Specific gravity	Tuber weight	Specific gravity
	g.		g.		g.		g.		g.	
1	101.1	1.060	208.8	1.065	80.0	1.070	44.7	1.080	41.8	1.089
2	93.8	1.062	152.8	1.068	56.0	1.069	39.6	1.088	40.3	1.078
3	79.8	1.067	120.8	1.077	49.8	1.073	33.6	1.090	35.8	1.088
4	66.8	1.081	143.8	1.067	49.3	1.074	30.0	1.098	22.3	1.093
5	66.2	1.064	114.8	1.072	36.3	1.077	21.1	1.088	19.8	1.100
6	43.4	1.093	65.8	1.068	29.3	1.093	18.8	1.099	19.3	1.096
7	39.8	1.073	64.8	1.073	20.3	1.093	13.8	1.095	10.3	1.097
8	24.8	1.100	51.0	1.080	15.8	1.082	7.9	1.092	8.5	1.118
9	20.8	1.089	46.8	1.081	12.3	1.098	—	—	—	—
10	15.2	1.078	38.5	1.078	6.8	1.114	—	—	—	—
11	11.2	1.098	11.5	1.084	—	—	—	—	—	—
12	—	—	9.8	1.077	—	—	—	—	—	—
Average	51.2	1.079	85.8	1.074	35.6	1.084	26.8	1.091	24.8	1.094

It was proved as early as 1880 by Behrend that the specific gravity of potatoes and starch value have a pretty close relationship. Estimation of starch from specific gravity has been put to practical use to a considerable extent.

We picked up at random 8–12 from the tubers in each region, so as to include all the sizes of big, medium and small and measured the specific gravity of each tuber. Table 13 shows the results of this experiment.

In the average value, E>D>C>A>B, in the contrast with the average weight of tubers examined. Examining variants in each region, we shall find in each region, small tubers are, in general, liable to have higher specific gravity than big ones. Thus we can see that the difference of specific gravity is greatly caused by that of the proportion of big ones among the tubers. picking up tubers as big as possible, namely those weighing more than 40g., and comparing them, we got the following results, as seen in Table 14.

Table 14. Comparison of the specific gavity of tubers weighing more than 40 g.

Region	Number of tubers examined	Average weight of tubers examined	Average specific gravity
A	5	20.4	1.088
B	3	19.9	1.080
C	6	20.1	1.093
D	7	24.3	1.093
E	7	22.3	1.095

As a general tendency, those in the open air have lower specific gravity. According to the measurement of average value, we shall find the significant difference between E and B region.

5. Conclusion

When we compare the open air with the greenhouse, differing in temperature, we find a high-temperature region in the green-house is different from the open-air regions, both tops and underground parts, becausee the high-temperature condition causes unbalance to such physiological phenomena as assimilation, respiration, etc. and hinders the yield of tubers, just as the results in chapter 1 prove. What interests us here is that the atmospheric temperature being high, the underground temperature, low or high, exerts no influence whatever. The Agricultural Experiment Station of Chugoku and Shikoku* says, "In a high-temperature region set up specially in the greenhouse, the effects of underground

* See. p.

temperature are not much clear, since it is covered by atmospheric temperature, while a drop of underground temperature lessens, it seems, the hindrance action of high atmospheric temperature." In our experiment, however, we could not find any trace of this reducing faculty of underground temperature. I wonder if this was due to the difference of temperature conditions in a high-temperature region. In this experiment, the maximum temperature was 30°C–35°C, while in those of the above station, it was 30°C±2°C.

In the three regions in the open air, atmospheric temperature was all in a normal condition, but underground temperature was varied, while the regions cooled by city water were in an unhealthy condition, even seen by naked eyes, probably because the artificial unbalance between atmospheric temperature and underground temperature caused abnormal physiological actions of the root, where by assiinilation and other physiological actions of tops became unhealthy, and at last the general growth itself came to be unusual, thus undesiable results for the yield of tubers were produced.

In this experiment, the underground regions where city water was left as it flowed, was 12°C–20°C. Werner[22] (1935) reports that as soil temperature rises from 13°C–20°C, the yield of potatoes drops. Taking these together, we know that underground temperature alone is an unfavorable condition to the yield of tubers. But the above-mentioned Werner's report as well as those of Smith[19] (1931), Tanaka (1937) et al. which endorse the opinion that a drop of underground temperature causes the yiely of potatoes to increase, is based on the preiniss that underground temperature and atmospheric one work relatively to some extent. The view of Emerson's (1914) that litter is effective because it drops underground temperature has a quaestion, with regard to the degree of the drop. When we consider our expermient, taking all of those reports into consideration, we may suppose that the unbalance between artificially dropped underground temperature and atmospheric temperature gives undesirable effects on physiological action of the plant.

Region A and B have been in a healthful condition, when seen by naked eyes. It may be supposed that the difference of underground temperature and that of soil moisture combined have brought forth the difference in top growth and in the end caused some difference in the yield of tubers. It is needless to say those plants whose top growth is good have good absolute yield of tubers, but the yield of tubers per unit top weight and unit leaf weight is also good. This probably because environmental conditions desirable to the quantitative top growth display a high efficiency, with regard to the function of the accumulation of assimilation products. But the quantity of top growth and its function are not to be con sidered equally, but have a certain limitation. We have here considered only what we call the phase of normal growth.

III. Effects of the difference in environmental conditions of underground part of the potato plant on tuberization

1. Forward

When different plants are grown in different environmental conditions, the difference in conditions of tops makes physiological phenemena of tops such as assimilation, respiration, etc. different, thus growth phase itself becomes different. In the same way, different conditions of undreground parts bring forth different physiological phenomena of the root, which affects in turn the growth phase. The difference in growth phase naturally exerts influence on the development conditions of tubers. On the other hand, the difference in soil conditions of underground parts is supposed to give direct influence on tuberization. Consequently, how environmental conditions, factors, of tops and underground parts combined, will affect tuberization is a problem which requires careful consideration.

In the present experiments, setting aside the problem of tops for the present, we made underground parts only the object of our study and examined how the degree of tuberization in the region, namely that of accumulation of assimilation matters will change, according to the different conditions in the region where tubers of underground parts are formed. These experiments were made from May to July, 1950.

2. Materials and methods

The variety we use was *Danshaku* plants were germinated and each sprout was planted in wooden box, 35 cm. by 35, with a sliding door on one side on April 20. In sowing seeds and covering them with earth, the seeds were laid at a place 10 cm. from the bottom. They were covered with earth in turn, as they sprouted. The last germination took place from May 20 to May 22, and the sprouts were laid on boxes, with different soil conditions of the underground parts after germination–A (top, bottom) and B (top, right and left, bottom, right and left). See Fig. 8.

Plants were dug on July 1 and observation was made chiefly on underground parts.

3. Results

(i) Underground temperature (soil temperature)

Underground temperature was taken at the points of 5 cm. and 15 cm. from the surface of the earth, in Region A located at 2/3 from the middle of the box,

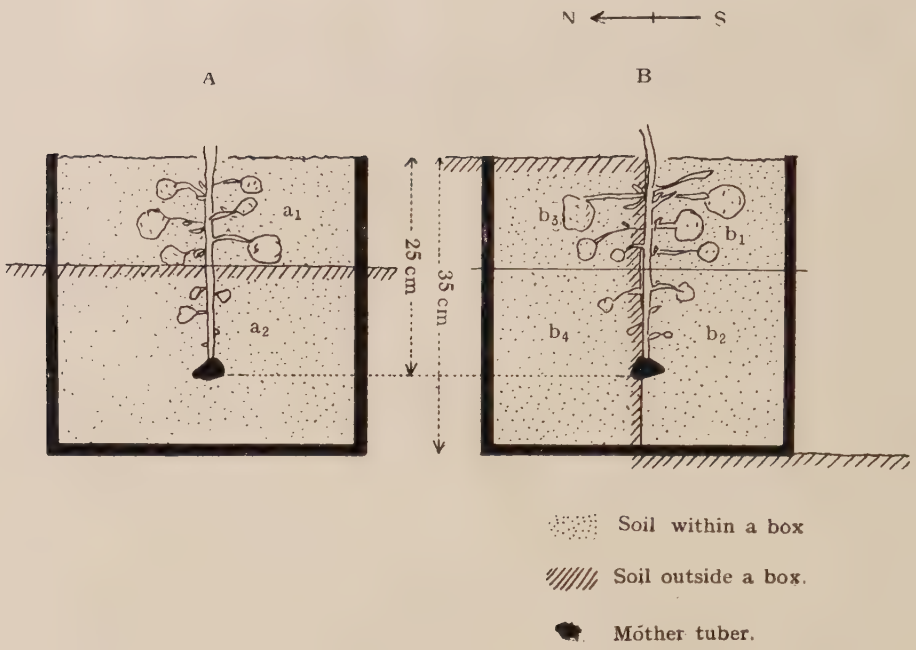


Fig. 8. Planted conditions of a plant.

at the two places of eastern and western sides, and in RegionB, at the four places of the southern sides of b_1. b_2 regions, and at the northern sides of b_3, b_4. Table 15

Table 15. Comparison of underground temperature in A experiment region.

Date	Weather	a_1				a_2			
		Maximum	Minimum	10 A.M.	Range	Maximum	Minimum	10 A.M.	Range
June 13	Fine	27.3	12.0	21.5	15.3	22.3	17.0	20.0	5.3
" 23	Fine	22.1	17.8	—	4.6	19.0	18.2	—	0.8
July 1	Cloudy	20.0	17.0	20.0	3.0	18.5	18.3	18.3	0.2
" 6	Fine	24.0	17.1	20.2	6.9	19.5	17.5	18.0	2.0

Table 16. Comparison of underground

Date	b_1				b_2			
	Maximum	Minimum	10 A.M.	Range	Maximum	Minimum	10 A.M.	Range
June 13	27.4	12.3	21.2	15.1	24.2	15.9	21.0	8.3
" 23	22.9	17.7	—	5.2	22.6	18.0	—	4.6
July 1	20.3	16.8	20.0	3.1	19.3	17.3	19.3	2.0
" 6	22.0	17.0	19.8	5.0	20.0	17.2	18.0	2.8

and 16 show the results.

In A experiment region, the upper part (a_1) is higher 2–5°C than the lower part (a_2) in the maximum temperature, while in the minimum, the former is rather lower, therefore in the range, a_1, is clearly higher than a_2.

In B experiment region, the maximum temperature is in the order of b_1 (southern side, upper), b_2 (lower), b_3 (northern side, upper) and b_4 (lower), but there is no striking difference in the minimum; therefore the order of the range is just the same as in the case of the maximum, though not so remarkble difference as in Region A.

(ii) Soil moisture

In Region A, $a_2 > a_1$. Against the proper moisture of a_1, a_2 has a tendency of having a little excess of moisture.

In Region B, the difference between the upper and lower is greater than that between the southern and northern parts. Of these parts, b_1 has a dry tendency, but it is not too much.

The relative difference of aëration is naturally to be considered with that of moisture.

(iii) Observation on the plant

Plant were dug on July 17 and observed. As to the conditions of the plants, at that time, the average height was 54.0 cm. but leaves were dead and fell off, only stems being left. The comparison in the development conditions of stolons and tubers of underground parts, which is main object of the present experiments, is as follows.

(a) A Experiment region.

Six plants were examined about the stolons and tubers, grown from the upper half and lower half of the main stems under ground. Table 17 shows the results.

Of the number of stolons, that of available ones is clearly greater in a_1 but in that of unavailable one, there is no essential difference between a_1 and a_2. The stolons in a_1 are still longer than those in a_2.

temperature in B Experiment region.

b_5				b_4			
Maximum	Minimum	10 A.M.	Range	Maximum	Minimum	10 A.M.	Range
23.2	15.6	20.0	7.6	18.9	11.8	15.8	7.1
21.1	18.1	—	3.0	18.2	17.4	—	0.8
20.0	18.0	19.5	2.1	18.5	18.1	18.2	0.4
19.5	18.0	19.0	0.5	18.5	18.0	17.2	0.5

Table 17. Comparison between upper and lower parts concerning the development conditions of stolons and tubers in A Experiment region.

Region	No. of atolons		Average length of available stolons	Number of tubers	Tuber weight g.	Average tuber weight per piece g.
	Available	Unavilable				
Upper (a_1)	11.3	4.3	5.11	12.1	369.8	30.4
Lower (a_2)	5.0	3.3	1.46	5.0	99.2	19.8

A_1 has far more tubers than a_2, as in the case with available stolons. Both the yield of tubers and the size per piece are greater in a_1. In short, in the point of the producing faculty of tubers, the upper region is superior to the lower one.

(b) B Experiment region.

The comparison among the four regions of the underground parts concerning the development conditions of stolons and tubers is shown by Table 18.

Table 18. Development conditions of stolons and tubers in B Experiment region. (Average of 5 plants).

Region	Number of stolons		Average length of available stolons	Number of tubers	Tuber weight g.	Tuber weight per piece g.
	Available	Unavail-able				
Southern upper (b_1)	6.25	1.50	3.60	6.25	286.0	45.8
Lower (b_2)	1.00	1.25	0	1.00	16.5	16.5
Northern upper (b_3)	4.25	2.00	1.45	4.25	165.3	38.9
Lower (b_4)	0.50	1.25	0	0.50	9.8	19.6

Both the number of stolons and that of tubers are in the order of b_1, b_3, b_2 and b_4. In short, the difference between the upper region and the lower is great, no substantial difference being seen between b_2 and b_4. Available stolons are longest in b_1, and second in b_3. In b_2 and b_4, stolons do not elongate at all, but show a condition of accumulating directly store-matters in the main stems under ground.

The number of unavailable stolons is very small, but b_3 has a tendency to be somewhat greater in it. There is hardly any difference among the rest.

In the average tuber weight both per plant and per piece, $b_1 > b_3 > b_2 \fallingdotseq b_4$; b_1 is heaviest in average. The difference between the upper part and the lower is striking.

It is due to high temperature, great range, suitable soil moisture and accordingly probable good aëration that b_1 yields the most tubers; in other words, soil conditions exert a great influence, it is considered. But when we compare

b_2 with b_3, the former is rather nearer to b_1, in soil temperature condition, but the latter is evidently suitable to the yield of tubers. Such being the case, the yield does not merely depend on the single element of soil conditions, but on many other factors organically correlated. The essential difference in accumulation faculty according to the position of the main stems under ground, upper or lower, is another great factor of influencing the yield, we consider, from these two experiments of A and B, though it is dangerous to conclude in a hurry.

3. Conclusion

When we lengthen main stems from which stolons sprout under ground, bury thier lower half (A Experiment) and northern half (B Experiment) under the soil, and let tubers yield, the conditions of taking of stolons and tubers differ markedly between upper and lower, or right and left. Since there is no absolute difference in bearing conditions of stolons and tubers, according to the position of the main stems under ground, the difference in soil conditions plays an important part. Especially in A Experiment region, there is a striking difference in temperature and soil moisture between upper and lower, In the upper part, the maximum temperature is high, the range great, and soil moisture not too much compared with that of the lower part, accordingly aëration is good, it is supposed.

In B experiment region as well, the southern upper part takes tubers better, since this part has the same conditions as those above described, it is considered.

In this experiment region, there is no striking differece in soil temperature condition between b_2 and b_3, but the latter takes tubers better. Why is it so ? If temperature remains within a certain degree, do other environmental conditions of soil exert a great influence ? Or does the accumulation faculty of the main stem under ground play a large part ? We cannot decide which, from this experiment only. If we accept the latter view, we should include, among the reasons why a_1 and b_1 take tubers better, the difference in internal elements of the plant, not to mention of that in soil conditions.

Of sweet potatoes, Nishiuchi[14] (1944) emphasizes the importance of temperature as the cause mechanisim of relative difficulty for assimilated products to accumulate under ground or of their more or less quantity. He says that tubers of sweet potatoes are formed in regions with low temperature during the day time or where temperature inclination is sharp, that the more greatly temperature changes, the larger tubers are liable to get, and that therefore, tubers are best formed aronud 10 cm. underground.

Of underground parts, the upper part is greater in the change of temperature, namely in the range, therefore it is not impossible to apply such a view as his to the potato plant as well. But it is not easy to conclude if this same view will hold good here.

Noguchi[15] (1944) tells that soil air (0_2) is a very important element to the growth and yield of a crop, and according to Sugawara's experiment, the yield of tubrs of the potato plant.

IV. Effects of the difference in soil structure on tuberization of the potato plant

1. Forward

It is a well-known fact that potatoes grow best on a sandy loam well drained in excellent condition of tilth, the scientific researches of which are, however, few. In view of this, Yamamoto and Ōizumi (1949) studied about sandy and clay loams. They reported on (1) the difference in the growth of different potatoes, namely in tuberization between the two kinds of loam, and on (2) the difference in the development of stolons and tubers, when one plant is planted in a region whose right side loam is sandy and left one clay. The present study may be said to be a continuation of their reports. But about the second point, we made soil conditions more excessive, in order to see clearly the effects of the difference in soil structure, planted on a deep box so that there might be as little difference in soil temperature as possible between the upper part and the lower one under ground,

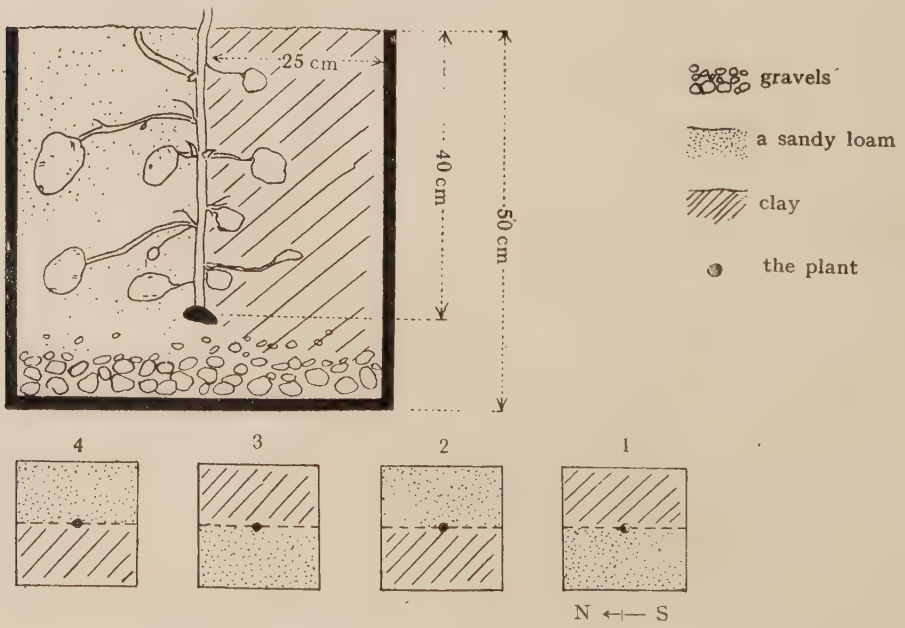


Fig. 9. Conditions of plantation and setting up of plants to be examined.

and observed the results. The present experiment were made from April to July, 1949.

2. Materials and methods

The variety we used was *Danshaku*. seeds weighing 30g. were sown in large wooden boxes of 50 cm^3, one side of which could be opened. Up to 10 cm. from the bottom, gravels were put in, so as the main stems under ground might grow as long as 40 cm. Putting a boundary plate from north to south in the middle, we covered one side with a sifted sandy loam the other with a clay one, three times successively as germs elongated. Clay loams we used were dried by wind, crushed and sifted. Seeds were sown on April 20, and the last germination in the box took place on May 10. Fig. 9 shows how the plant grew in the box.

3. Results

(i) Development of stolons.

Will the time when atolons growing at their tips turn into tubers differ according to the kinds of loam ? To see this, plants were dug on June 5 and examined. But we could not find out any quailtative difference, as Yamamoto and Oizumi had observed. It is because tuber formation due to a physiological change of the plant as a whole ?

The conditions of stolons at the last examination which was held on July 25 are shown by Table 19.

Table 19. Difference in the number of avairable and unavailable stolons and those turned into stems and leaves, according to the two kinds of loam.

No. of plants	Available stolons		Unavailable stolons		Stolons turned into stems and leaves*	
	Sandy	Clay	Sandy	Clay	Sandy	Clay
1	8	7	13	4	4	1
2	7	6	3	2	1	0
3	3	1	9	5	1	0
4	6	3	5	8	0	0
Total	24	17	30	19	6	1

N.B.* : Of unavailable stolons, those which are about to turn into stems above ground.

Both availabel and unavailable stolons are greater in number with sandy loams. So may be with those which are turned into stems and leaves, though their absolule number is not so great. In short, sandy loams are superior, in the number of stolons.

The results show that sandy loams are more adapted to the numerical development of stolons sprouted from the main stems under ground. Does the tendency that sandy loams grow more stolons which turen into stems and leaves show not that this kind of loam is better adapted to their growing, while the other one checks it mechanically? Table 20 shows the comparison of the length of stolons. It is to be seen that sandy loam regions grow longer stolons. In short, we can see that sandy loams are better adapted to the development of stolons in quantity as well as in number.

Table 20. Comparison of the length of Available stolons.

Number of plants	Sandy loam cm.	Clay cm.
1	2.75	4.17
2	7.17	4.80
3	14.00	6.00
4	7.17	6.75

(ii) Development of Tubers.

What are the development conditions of tubers formed from the above available stolons? The comparison of them between the two kinds of loam is as Table 21.

Table 21. Comparison of the development conditions tubers between sandy loams and clay.

No. of plants	Number of tubers		Total weight of tubers (g)		Average weight per piece (g)	
	Sandy	Clay	Sandy	Clay	Sandy	Clay
1	8	7	239.5	99.0	29.9	14.1
2	7	6	358.0	71.0	51.1	11.8
3	3	1	165.0	75.0	55.0	75.0
4	6	3	211.0	111.5	35.2	37.1
Total	24	17	973.5	356.5	—	—

The number of tubers is just the same as in the comparison of stolons. In the comparison of the total weight of tubers, every individual is heavier in a sandy loam. The average tuber weight per piece is clearly in a sandy loam with Nos. 1 and 2; with the others, the results are unsatisfactory, as the number in clay region is too small. As to the size of individual tubers, the difference will be more apparent, if we see the dispersion of tubers in both regions, according to their size. As seen in Table 22, clay loam region got no tubers weighing over 80g.,

while sandy one got as many as two weighing more than 100 g.

Table 22. Dispersion of Tubers in the two loam regions according to their size.

Region \ Dispersion according to size	Up to 10g.	20g.	30g.	40g.	50g.	60g.	70g.	80g.	90g.	100g.	Over 100g.
Sandy loam	9	1	2	1	3	1	1	2	1	1	2
Clay	7	3	2	1	2	0	1	1			

In short, a sandy loam is better suited for tubers to get big.

(iii) Specific gravity of tubers.

When we compare the specific gravity of tubers, an index of their quality, about those up to 70g. in both regions, we can see no difference according to the regions, though their size varies. In a sandy loam, it is 1.078–1.099, 1.091 in average, while in a clay regin, it is 1.078 1.098, 1.091 in average.

According to the results of Yamamoto and Ōizumi, there was no difference in the specific gravity of tubers according to regions, so was in those of our experiments.

(iv) Lenticels of tubers.

The development conditions of lenticels of tubers differ greatly according to regions, even seen by naked eyes. We observed the conditions of those lenticels in the tubers formed in sandy and clay loam regions. Table 23 shows the

Table 23. Comparison of the development conditions of lenticels according to a sandy loam and clay.

Tuber Nos.	Sandy loam			Clay		
	Size of tubers (g)	No. of lenticels (mm)*1	Size of lenticels (mm)*2	Size of tubers (g)	No. of lenticels *1	Size of lenticels (mm)*2
1	113.0	5.5	0.88	—	—	—
2	112.0	5.2	0.87	96.0	4.3	1.34
3	76.4	5.2	0.88	75.1	5.1	1.52
4	48.7	4.3	0.77	44.5	5.2	1.35
5	42.8	5.7	0.63	45.5	5.4	1.31
6	39.7	5.4	0.53	26.4	5.0	1.11
7	20.7	5.4	0.44	24.0	5.7	12.7
8	10.5	5.4	0.49	7.0	5.5	1.14

Note : *1 Number of lenticels within every 1 cm^2. Average of 6~10 in a tuber.
*2 Measurement value of major axis, average of 10 lenticels.

results.

In the comparison of the number of lenticels contained within every 1 cm² on the surface of the epidermis of tubers, there can be seen no essential difference according to the kind of loam. But in the size of lenticels, tubers formed in clay are far greater.

The difference in the size of lenticels is probably due to the one in water physiological phenomenon based on the difference in the quantity of contained water between the two loam regions.

(v) Soil temperautre and humidity.

The difference of quality between a sandy loam and clay is probably caused by the disparity in various physical conditions. In the present experiments, we first measured soil temperature and humidity.

We took the soil temperature at the point 20 cm. under the surface of the earth and 12.5 cm (middle) from the wall of the box. Table 24 shows the results. The results of Yamamoto and Ōizumi were from the observation in a farm. They report that the difference in temperature between the two loams is as great as 4.5°C under a fine weather. Little difference was to be seen from our observations which were made on June 23, a fine day and on July 10, a rainy day. Ours being the cultivation in boxes on the ground, the atmospheric temperature might have influenced all over the boxes, which was perhaps the reason we could see little difference in our measurment of temperature.

Picking up soil at 20 cm. under the surface of the earth, we measured its humidity, in which a sandy loam is clearly greater as seen in Table 24.

Table 24. Comparison of soil temperature and humidity between a sandy loam and clay.

Date	Soil temperature									Soil humidity	
	Region	O'clock 0	3	6	9	12	15	18	21	%	Quantity of contained water %
June 23 Fine	Sandy	18.5°C	18.1	17.7	17.5	18.0	21.5	20.5	19.0	14.1	29.4
	Clay	18.5°C	18.2	17.6	17.1	17.5	21.1	21.0	19.0	24.9	38.9
July 10 Rainy	Sandy	17.5°C	14.3	13.0	17.8	21.5	24.5	22.5	19.1	15.6	32.6
	Clay	18.1°C	15.1	14.5	17.7	21.0	22.5	21.0	19.2	27.8	43.5

N.B.: Quantity of contained water ..... 47.5% in a sandy loam and 63.5% in clay.

4. Conclusion

By making the quality of soil different between the right and left of the same

individual, we can see striking difference in the development of stolons and tuberization. A sandy loam has more suitable conditions and is superior both in the elongation and development of stolons and tuberization.

As a reason that a clay loam is not suitable to tuberization, Yamamoto and Ōizumi state, "In a clay loam, the bigger tubers get, to the greater pressure must they be subject, so they cannot be great potatoes, we suppose." Such a mechanic action may be an element which prevents tubers from becoming big, but it is unreasonable to suppose that this is the only ruling factor.

Soil temperature, humidity and aëration vary with soil structure. Therefore, it will be reasonable to suppose that all these conditions combined, a sandy loam is more suitable than clay.

No difference can be seen between the specific gravity of tubers produced in these two kinds of loam, but in the development of the size of lenticels, difference is remarkable, the development in clay being greater. This is probably due to the difference in water physiological phenomenon based on the difference in the quantity of contained water between the two kind of loams. Will the difference in the size and development of lenticels not exert a pretty great influence on the value as goods?

So far we have made observations on how the difference in soil structure under ground will affect the yield of tubers in the same individual. But what about the results when various individuals are planted on soil with different soil structure? Of which Yamamoto and Ōizumi report that those planted in a sandy loam from tubers early and tuberizes fast and have many large potatoes weighing heavy at the harvest-time and explain that this is because the difference in soil structure affects the potatoes synthetically and makes the top growth great.

V. Effects of the difference in soil humidity on tuberization

1. Forward

In regard to the effects of soil humidity on the growth of the potato plant and the yield of tubers, Johanson and Boyle (1920) report that extremely moist soil injures the quality, while Hadenburg[11] (1923) made his experiments on soil with the humidity of 17.20 and 23 % respectively and states that the weight of potatoes depends upon humidity and the number varies with temperature. And Weaver[8] (1926) observed fully on the relation between the root development and the amount of contained water in soil. According to the recent experiments by the Agricultural Experiment Station of Chugoku and Shikoku,[7] both extreme dryness and moisture are quite undesirable to germination, but when the amount of contained water remains 50–70%, no great difference is caused, and nothing

but extreme dryness makes a great difference it the early growth of the root and stolons.

The various reports made thus far cannot be said to have arrived at a decisive conclusion. In view of the fact, moreover, that there goes a notion that the function of the seed potato is to absorb water when it is moist and supply it when dry, it seems that the problem of soil humidity has been neglected. In our experiments, we wanted to criticize many reports made hitherto, and at the same time have observed what effects the difference in soil humidity will give to the growth of potatoes and tuberization. They were made from April to June, 1950.

2. Materials and methods

We used seed potatose weighing about 30g., the variety of which being *Danshaku*. They began to germinate from March 17, at the temperature of 20°C. Each sprout was planted on April 4 in a Wagner's pot 1/20,000. Till a certain stage of growth, they were all grown under equal conditions. On May 10, in average the height became 30 cm, the length of stems 15 cm. and the number of leaves 9 or 10. From that time, they were moved to various treatments.

The method of treatment was as follows. Into a big concrete water tank, placed on a wooden stand, were put three pots for each treatment. We arrange five regions differing in water-level one another and another outside the tank, making six in all. In the tank city water was left as it ran.

The devise of treatment is explained by Fig. 10.

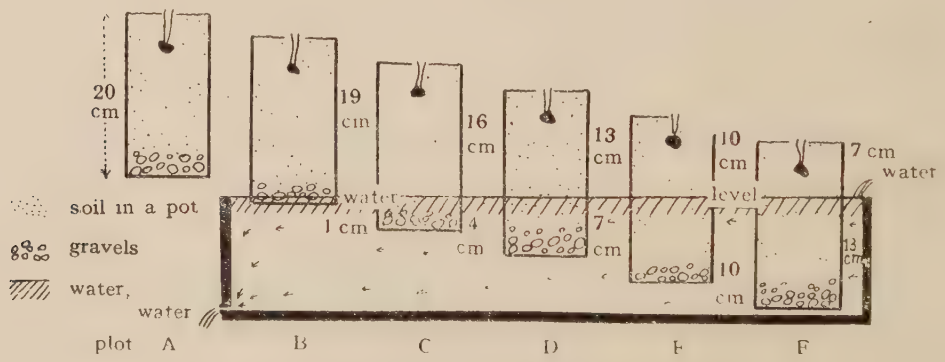


Fig. 10. Model illustration of the device of treatment.

These six regions were named A, B, C, D, E and F respectively. A region outside the tank was watered morning and evening so as not to be withered.

During the treatment period, all the windows in the green-house being left open, we tried to make the temperature condition within and without same as

much as possible. Digging all the individuals on June 4 when the top gowth was at its height, we investigate them,

As the treatment conditions of soil, measured not only the amount of contained water in clods, but also soil temperature.

3. Results.

(i) Soil humidity and temperature

The soil humidity of the six treatment regions was measured at 5 cm. under the surface of the earth on May 18 and May 30, twice each time. Table 25 shows the results. The soil we used was an ordinary sandy loam, the amount of contained water of which was 55 %, and gravels were sifted with a sieve of 1.5 cm. Soil material was picked up at about 1 in the afternoon.

Table 25. Comparison of soil humidity.

Region	Measured on May 18	Measured on May 30	Average	Amount of contained water %
A	19.3	14.2	16.75	30.4
B	19.7	22.2	20.95	38.1
C	29.9	24.6	27.25	49.3
D	41.2	46.3	43.75	79.3
E	47.0	46.4	46.70	84.9
F	53.8	62.5	58.15	105.7

Soil humidity increased from Region in due order, but from D on it became greater especially, and in Region F, it reached almost the saturation point. Although Region A was adjusted by being watered morning and evening, sometimes it probably fell into an extraordinary dry condition.

Now we shall came to soil temperature. The object of our experiment is to see the difference in soil humidity, so with a view to lessen the disparity in soil temperature as much as possible, we planted early, choosing the time when there

Table 26. Comparison in soil temperature among all the regions.

Range	Maximum temperature	Minimum temperature	Temperature at 10 AM.
A	20.3 (15.0–22.5)	14.0 (12.1–16.8)	17.0 (12.2–19.9)
B	20.2 (16.0–23.7)	14.0 (12.1–16.5)	16.9 (12.2–19.0)
C	19.8 (15.0–23.5)	14.0 (12.0–16.6)	17.0 (12.1–19.7)
D	19.6 (14.8–23.0)	14.1 (11.9–17.0)	16.9 (13.0–19.0)
E	19.4 (15.0–22.1)	14.3 (12.0–16.8)	16.9 (13.0–19.5)
F	19.3 (15.3–22.0)	14.2 (12.7–16.4)	17.0 (12.0–19.8)

N.B. : Taken at 7 cm. under the surface of the earth.

is little difference between atmospheric temperature and water one, and tried to make the difference among B-F as little as possible, by keeping city water running all the time.

We took soil temperature during experiment period from May 18 to May 27. The comparison in the maximum temperature, the minimum and the temperature at 10 in the morning in average is shown by Table 26.

(ii) Growth of tops.

When we compare the growth conditions of tops, about height, top weight and leaf weight, the results are as follows Table 27.

Table 27. Comparison in the growth of tops.

Region	Height cm.	Top weight g.	Leaf weight g.	Top weight / Height	Leaf weight / Top weight
A	44.2	105.5	45.4	2.39	0.43
B	80.1	292.3	141.3	3.65	0.48
C	82.7	388.6	183.7	4.69	0.47
D	84.8	460.6	185.3	5.43	0.40
E	84.7	474.6	209.0	5.60	0.44
F	84.0	484.3	215.3	5.77	0.44

In regard to height, Region A with the least soil humidity is evidently most inferior and next comes Region B. Among the rest four regions, there is no substantial difference. In regard to top weight and leaf weight, the greater humidity is, the greater their value becomes. Especially Region E is superior to others.

The ratio of top weight to height becomes graeter, as soil humidity increases more and more. In short, great humidity tell that the growth of tops is vigorous. On the other hand, in regard to the ratio of leaf weight to top weight, Region B

Table 28. Comparison in the development of stolons and tubers of underground parts.

Region	Available stolons		Unavailable stolons		Tuber weight per individual g.	Tuber weight per piece g.	Tuber weight / Top weight	Tubert weigh / Leaf weight
	Length	Number	Length	Number				
A	4.46	3.3	1.31	13.7	20.7	6.7	0.02	0.46
B	2.76	5.0	2.09	12.0	82.3	18.7	0.28	0.58
C	3.07	8.0	1.11	15.3	100.5	12.8	0.26	0.55
D	3.16	7.7	0.97	11.3	88.0	11.4	0.19	0.47
E	3.91	8.7	0.86	17.3	95.5	11.1	0.20	0.46
F	2.92	9.7	0.84	8.7	101.0	12.7	0.21	0.47

and C, namely those with humidity of 20–30 %, show the heighest value.

The development conditions of stolons and tubers of underground parts are shown by Talbe 28.

The number of available stolons is greater in A than in any other region. Thinking of variants within each region, we cannot imagine there is any essential difference among other regions. Up to Region C, the number of available stolons becomes greater with the increase of soil moisture. There is no qualitative difference among further regions. There cannot be seen any definite tendency in the length and number of unavailable stolons. In the average tuber weight per individual, extremely dry Region A is quite inferior, but among other regions there is no striking difference, if anything, Region C and F are a little superior, but it is doubtful if they are essentially superior. In the average tuber weight per piece, Region A is still inferior to any other, while Region B is most superior, among the rest, there is no qualitative difference.

In the absolute quantity in the above-mentioned yield of tubers, we can see that the extremely dry region is clearly inferior, but among the rest, there is no striking difference, but if we venture to say, B and C are greatest.

If we examine the ratio of tuber weight yielded to top weight and to leaf weight, we shall find that soil humidity of B and C, namely 20–30 % is most satisfactory. The fact that tuber yielding faculty and the ratio of leaf weight to top weight coincide may tell that there is some relationship between them.

(iv) Lenticels of tubers.

We have already reported that lenticels on the surface of the epidermis of tubers differ in size according to soil structure. In this experiment, we observed how they will vary with the difference of soil moisture. We picked up five tubers from each region with the uniform size of about 15g. and examined them.

Lenticels become larger with the increase of soil moisture. Their number is

Table 29. Comparison of the size and number of lenticels of tubers.

Region	Size *1		Number *2	
	Range	Average	Range	Average
A	6–13	9.23	6–13	9.9
B	8–15	10.90	6–15	11.8
C	9–16	13.20	8–12	10.3
D	12–25	17.20	8–13	11.1
E	12–24	16.37	8–14	10.9
F	15–30	21.45	8–15	11.9

Note : 1. Major axis of lenticels was measured by 1×5 field micrometer.
2. The number contained in a circle of 1.2 cm. dia. Measured at 10 points each tuber.

somewhat smaller in Region A, but there may be no essential difference in it among all the regions.

(v) Specific gravity of tubers.

We observed how the specific gravity will differ among tubers produced in regions with different soil moisture. We measured that of five tubers, large and small, picked up from each region.

Table 30 shows the results in average value.

Table 30. Comparison of the specific gravity of tubers.

Treatment region	Average size of tubers g.	Average specific gravity
A	8.16	1.116
B	21.54	1.090
C	18.40	1.098
D	16.78	1.078
E	17.86	1.093
F	18.46	1.088

The specific gravity in Region A is clearly greater than that in any other regions, statistically as well. Among the four regions of B, C, E and F, there is very little difference, but region D has a smaller specific gravity, which might be cause some other elements than soil humidity, conciderring the relation with its near regions.

In short, it will be reasonable to consider that we cannot see any striking difference among the five regions except A.

Why region A is greater in specific gravity than the rest? Probably two causes can be thought of it. First, this region is driest and so the amount of contained starch is great, consequently specific gravity also becomes great. This is the essential difference.

Next, as is generally recongized, small tubers have a greater specific gravity than big ones. Those tubers picked up from Region A were naturally small, accordingly they had great gravity.

4. Conclusion

As to the effects of soil humidity on the top growth and the yield of tubers, when humidity is especially small, in other words, when the amount of contained water is about 30 %, bad results are produced, but when it is more than 40 %, there can be no striking difference. However, 40-60 % seems to be most desirable, so far as the ratio of the yield of tubers to the top growth, namely the yield function of tubers is concerned.

According to the results of experiments made by the Agricultural Experiment

Station of Chūgoku and Shikoku,[7] extreme dryness is undesirable to the development of underground parts as well as germination, but among other regions, there is no striking difference, but if we verture to say, 70 % in the amount of contained water, is most desirable.

When we consider this in connection with the view that the seed potato not only preserves water, but also supplies it in a day season, we shall see the effects of soil moisture on the potato plant must be considered to a great degree.

Next, in even Region F with soil humidity of saturation, potatoes themselves were kept from being decayed and other troubles. This is probably due to the fact that O_2 was pretty much supplied in the pots, since clear water was kept running all the time. As is generally believed, when potatoes are submerged with stagnant water, or if soil humidity reaches saturation, they are subject to decay, difficulty in respiration being caused.

In the present experiments, we made no observation on the relation between soil humidity and root development, but soil moisture has a close relationship with root development, in its connection with soil temperature, aëration, etc. Weaver[3] (1926) reports that when he made three regions of soil and sprinkled on each of them much, little or no water respectively, root developed deep in the region of much water, and in the one of no water, it spread shallow, while in the on with little water, it developed widest and deepest and the yield of tubers was greatest, too.

Johnson and Boyle (1920) made a report on the quality of tubers of the potato plant, namely on the relation between the amount of contained starch and soil humidity. They say that much rain reduces the quantity of starch. As is well known, the amount of contained starch is greater in a sandy loam with small moisture than in a clay one with much moisture.

IV. Effects of day-length on the turning period from stolon elongation to tuber formation of the potato plant

1. Forward

Studies on the effects of day-length on the potato plant were already made by Doroshenko[8] (1930), Arthur, Guthrie and Newell[1] (1930), Razumov[16] (1931), Beamomt and Weaver[3] (1931), Robert and Struck-meyer[17] (1938), Stelzner and Torka[21] (1940), Werner[22] (1940) et al. Their results are not always agree, because of difference in conditions such as temperature, etc. But in general we may safely say that the short-day condition stimulates tuber formation, as Stelzner and Torka and Werner report, while the long-day condition increases the yield of tubers, as Arthur, Guthrie and Newell, and Robert and Struckmeyer tell.

The Agricultural Experiment Station of Chūgoku and Shikoku has recently made a day- length treatment experiment and concluded that short-day hastens the differentiation and formation of tubers, while long-day delays them. According to our former observation, if we observe the periodic change of tuber weight, according to a short-day region, a natural day-length one and a long-day one, we find that short day shows the best results at the early stage of growth, but that at the later stage, long day becomes much better. This clearly shows the periodic difference in day-length reaction; as short-day stimulates tuber formation at the early stage of growth, the short-day region yields many tubers, but at the later stage when tuber formattion is completed and assimilation products begin to be accumulated which are to be determined by the growth of tops, the long-day region comes to yield more tubers.

The Jerusalem artichoke is another kind of plants, underground stems of which develop, that is, tuberize like the potato plant. It was reported by Garner and Allard (1923) many years ago and later by Ogasawara (1941) in our country that short days stimulate tuberization.

The fact that tuber formation of a potato plant is hastend or delayed tells that there are internal changes in the plant. We stated aboved that the change from stolon elongation to tuber formation is a qualitative one different from the developing process of tubers after that. This view is further confirmed by the study of the reaction of day-length. In the present experiments, we tried to realize how many day's treatment and how many hour's illumination are most effective for the short-day condition at the early stage of growth to promote the change from stolon elongation to tuber formation, hoping to make a stepping stone for further studies. Consequently, this alone will remain only a prediction, but as the day-length condition was treated as an environment, we want to report here under the head subject.

These experiments were made in June and July, 1950.

2. Materials and methods.

The variety we used was *Danshaku*. Potatoes were planted in flower-pots and when a certain time passed at the early stage of growth, we picked up only those which grew equally and began their treatment at the same time. Experiment was treated during 15 days from June 19 to July 3, at three treatment regions, namely 20 hour's region, 15 hour's one and 8 hour's one. Experiment 2 was treated during 10 days from June 25 to July 3, at five regions of 20, 17, 15, 11 and 8 hour's respectively. In the short day treatment, its regions were covered with wooden boxes early in the afternoon to get short time as hoped, while in the long day treatment regions, 2 day-light colour electric bulbs of 60 W. were shorn over them from 1 m. above to get supplementary day length.

The atmospheric temperature during the treatment peroid was at the maximum 25°C–31°C, at the minimum, 15°C–17°C, while 22°C–17°C at 10 O'clock in the morning.

3. Results

(i) Experiment 1.

At the beginning of the treatment, the growth of the plant was height 14–15 cm, the number of leaves 7–8, length of stolons under ground 0.49 in average. Of course they were all in the course of elongation.

The growth condition after 15 day's teratment is as Table 31.

Table 31. Growth condition of Tops after 15 day's treatment.

Range	Height cm.	Top weight g.	Leaf weight g.	Top weight / Height	Leaf weight / Top weight
20 hours	35.1	26.1	10.4	0.74	0.39
15 hours	32.6	28.6	11.5	0.88	0.40
8 hours	26.3	14.7	5.2	0.52	0.35

The longer days are, the longer plants grow in height, but both top weight and leaf weight are heaviest in the natural day-length region, next comes the 20 hour's one and the 8 hour's one is worst. The ratio of top weight to height is greatest in the second region, while the ratio of leaf weight to top weight is smallest in the last. Seen as a whole, the growth of tops is worst in the short day-length region. Between the other two regions, the first one is superior in height, but in the thickness of tops, the second is better. In the general sense of the growth of tops, the region of natural day-length may be said to be in most desirable conditions.

Next, let us observe the development conditions of underground parts. Table 32 shows the results.

Table 32. Development conditions of stolons of undergrround parts.

Region	Average no. of stolons per individuals	Average no. of stolons per piece	Total no. of stolons	Divisious of stolons				
				I	II	III	V	T
20 hours	6.3	4.4	25	25				
15 hours	4.3	4.6	17	3	2	7	3	2
8 hours	2.3	1.5	7	1	3	3	0	0

N.B.: One individual in 8 hour's region was excluded on account of trouble.

The number of stolons is greatest in the first region and smallest in the last, but in their length, there is little difference between the first two regions. Only two tubers were formed in the 15 hour's region, but none in the others. When we compared the progress of tuber formation from the difference in the forms at the tips of stolons, no sign of tuber formation was seen in the first region, while in the rest, it was clearly seen.

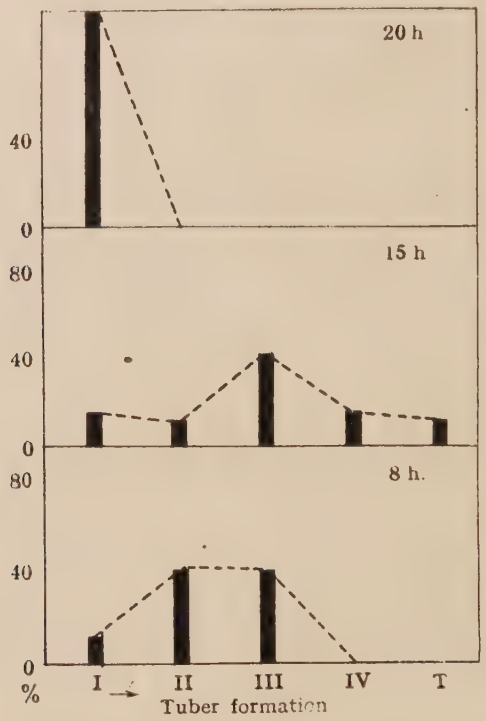


Fig. 11. Comparison of tuber formation progress among the day-length treatment regions of 20, 15 and 8 hours.

Fig. 11 shows this condition in percentage. Between the last two, the former seems to show more progress, but seeing that the number of the individuals was small and that in the 8 hour's region, other obstacles were seen, we cannot decide which is better in progress, from this observation only.

(ii) Experiment 2.

In this experiment, we made the period of treatment shorter than in the last one, and arranging its five regions, observed the reaction of day-length. The

growth conditions of plants at the beginning of this treatment are—height 16.5 cm., number of leaves 7–8, top weihgt 14.3 g., leaf weight 6.0 g. and length of stolons underground 0.5 cm.

The materials used in this experiment were slightly more developed than in the previous one.

Table 33 shows the comparison of the growth of the plants after 10 day's treatment.

Table 33. Comparison of top growth after 10 day's treatment.

Region	Height cm.	Top weight g.	Leaf weight g.	Top weight / Height	Leaf weight / Height	Leaf weight / Top weight
20 hours	32.0	29.5	9.5	0.92	0.29	0.32
17 hours	28.4	27.3	9.0	0.96	0.31	0.33
15 hours	30.8	28.6	10.7	0.93	0.35	0.37
11 hours	31.0	32.0	10.0	1.03	0.32	0.31
8 hours	30.0	32.8	9.0	1.09	0.31	0.29

In the height of plants, there is no striking difference among all the regions, top weight is somewhat heavier in the last two regions, and leaf weight is slightly better in 15 and 11 hours ones, but it cannot be considered to be any essential difference. In the growth conditions of tops against the height of plants, the short day-length regions or natural day-length one is liable to be better than the long one.

The ratio of leaf weight to top weight is greatest in the 15 hour's region. In short, in the growth conditions of tops, we can hardly find any striking difference according to various methods of day-length treatment during 10 days. If we venture to conjecture, the natural day-length region and short ones have a better tendency to grow as a whole.

As we have now seen, there can hardly be seen any difference in the top growth, but what about underground parts? The results of the examination are shown by Table 34.

Table 34. Development conditions of stolons of underground parts.

Region	Average no. of stolons per individual	Average length of stolons per piece	Total no. of stolons	Divisions of stolons				
				I	II	III	IV	T
20 hours	4.8	3.3	19	19	—	—	—	—
17 hours	4.3	5.6	17	17	0	0	0	0
15 hours	6.3	4.6	25	25	0	0	0	0
11 hours	4.3	3.3	17	8	9	0	0	0
8 hours	5.0	4.6	20	2	12	6	0	0

In the length and number of stolons, we cannot think that there is any difference among the regions, from this table, if we take variants of individuals in them into consideration. But in the progress of tuber formation, there is a marked difference between the last two regions and the rest ; it is clear short day length hastens tuber formation. In the other three regions, stolons are in course of elongation, and there appeared on difference among them during 10 day's treatment.

3. Conclusion.

Effects of different day-length treatments for 15 or 10 days at the early stage of progress on the degree of top growth of the plants hardly appear. But if we venture to say, in long day-length regions, the elongation of the height is great, while the thickness of tops is relatively inferior. May the most desirable growth condition not the natural day-length condition or slightly short day-length one ?

In Experiment 1, the growth was extreamely poor in the 8 hour's region, but this is because of some other obstacles, we suppose.

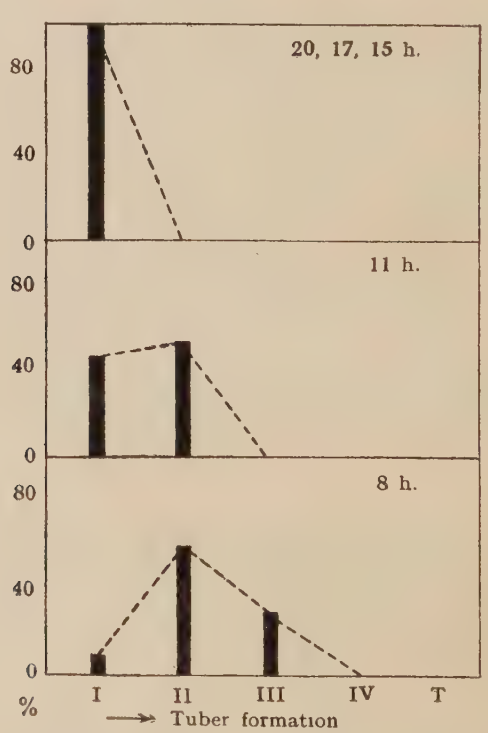


Fig. 12. Comparison of progress in tuber formation among the five regions of different day-length treatment.

On the number and length of stolons of underground parts, day-length treatments made no effects. Their influence on tuber formation of underground parts is striking. But the 15 day's treatment, in both 15 and 8 hour's regions, stolons began to swell only at their tips, but in the 20 hour's one, there appeared nothing like this. By the 10 day's treatment, in 8 and 11 hours regions, some stolons have already begun to from tubers, but in the other regions, nothing could be seen like that. In Experiment 1 of the 15 day's treatment, the 15 hour's region was better grown than the 8 hour's one numerically. But in this region, some other physiological phenomena to prevent growth having appeared, the number of stolons to be examined became extreamely small, accordingly we failed to get proper results, we suppose. At any rate, tuber formation in it has in fact gone further than in the 20 hour's region.

As we have now seen, a short day-length treatment for a short period at the early stage of growth hardly or very little affects the growth of tops, while it exerts clearly a promoting influence on tuber formation, to our great interest. This is also a material to confirm the view that "the change from stolon elongation to tuber formation is a qualitative one," as we have already described above. Ogasawara (1941) also express of Jerusalem artichokes the view that the differentiation of tubers is qualitatively different from their swelling. Well, report that a short day-length treatment promotes the accumulation of assimilation products in the undrground parts such as stems or roots, were made on other crops as well. On Jerusalem artichokes Garner and Allard (1923) and Ogasawara (1941), on dahlias Zimmerman and Hitchcock (1929), and on dahlias and other plants. By what mechanism will a short-day-length treatment promote the accumulation of assimilation products in such crops or plants ? Of this, it may be advisable for us to study first what a change this treatment will cause to the plant.

Zimmerman and Hitchcock reports of Jerusalem artichokes that the accumulation of nitrate was observed after this treatment. Moreover, reports of other crops or plants than tuberization of day-length teratments with their internal change are greatly helpful to our study of tuberization of the potato plant.

In their study of Jerusalem artichokes, Zimmerman and Hitchcock and Hammer and Long (1939) opine that since a short-day-length treatment to some parts of plants promotes the differentiation of tubers, some matters something like hormon produced in some regions of the plants may be the cause to the differention of tubers. This is a worthy opinion we can hardly estimate too much.

VII. Generalization

It is fundamental for the clarification of a cultivation theory on a certain crop and most impertant from the practical point of view that we should make clear the relation between the crop and its environments. So far many valuable studies and experiments have been made on the effects of environmental conditions on crops. Thanks to them, most of these effects have been brought to light, but there still remain many problems unsettled which depend upon more detailed studies. These problems are so many, if we count among environmental factors, temperature, humidity, day-length, soil structure and other minor ones. If we represent the object of a given crop by A and each facter by a,b,c,....., A=f (a,b,c,.....). It is a *sine qua non* to realize the quantitative relations among the facters of a, b, c,....., but when the object of our study is an animate thing, it is impossible to pick up a single element and test it only ; even if it were possible, since many facters operate correlated, the perfect solution of a question would be utterly hopeless. Such being the case, it is a long way to arrive at the decisive conclusion on the effects of environmental factors on the growth of the potato plant and the yield of tubers. Here we shall consider the significance of environmental facters on the potato plant in outline.

First, we should consider the absolute and relative qualities of each factor.

When a potato plant is put under an extreme condition beyond a certain limit, its effects will be very little or nothing. For instance, in a green house with high temperature more than 30°C, the balance between assimilation and respiration of top is upset, its growth becomes abnormal and the yield of tubers very bad. In this case, the disparity in underground conditions hardly produces any effects. On the other hand, with the difference of temperature by less than 30°C, other conditions of tops and soil conditions et al. of underground parts become to related to one another. In other words, the plant is subject the difference of combined environmental conditions.

Second, the fact that a plant differs in faculty, according to its parts like roots, stems and leaves, shows that the best adequate conditions required by each part vary from one another. But with the consideration of environmental conditions separating each part from other, we should at the same time contemplate balanced conditions as a whole, since a plant makes an organive operation. For example, it is considered that a relatively low-temperature condition is desirable for the potato plant, for both tops and underground parts. But if we artificially put underground parts only under relatively low temperature, abnormal growth will be caused. This is, it is imagined, due to the disparity between assimiration

of inorganic nutriment of underground parts or to the inequality of physiological functions such as respiration in both parts.

Lastly, in the process of growth, qualitative change as well as quantitative is to be seen. Consequently, the reaction to environmental conditions differs according to the time of growth. With the potato plant, for instance, the short day-length condition promotes tuber differentiation, but relatively long day-length gives better results to tuberization. And the importance of soil humidity varies with the time ; the time when needs most moisture is considered to be the flowering season, next the early and last stages of tuber formation.

Summary

I. Potato plants were translocated in the high-temperature conditions within a green house, at three stages of growth, namely, that of stolon elongation, the first and last stages of tuberization. Observations were made on what effects they will give to the later growth or developing conditions of tubers.

(1) Regarding the growth of tops, on account of high-temperature condition, the stem elongation is vigorous, but the development of lateral sprouts is bad ; in other words, they show a phenomenon of what we call waste sprout. This phenomenon becomes excessive, as the time becomes longer.

(2) In the region where plants were translocated after the stage of their stolon elongation, the change to tuber formation is delayed, the length of stolons becomes long, moreover, unavailable stolons grow in great number.

(3) The high temperature since the early stage of tuberization, affects its process at once with a preventing force. It exerts no influence on the number of tubers, as it has already been decided, but if the time of this treatment is long, tubers sprout again and are liable to become rounded thickening something like a neuter between stolons and tubers.

(4) In short, seen as a whole, this treatment causes specially striking bad results, when the plants were transolcated since the stage of stolon elongation.

II. Potato plants were grown in five regions with different temperature conditions and their effects on tuberization was observed. The five regions are two high temperature ones above ground (one with high temperature under ground and one with low temperature there, namely where city water is kept running) and three out of door regions (one where underground parts are buried under soil, on where those parts are left on the surface of the earth, and one hwit low temperature).

(1) In high temperature within a green house above ground, the yield of

tubers is worst, irrespective of temperature under ground.

(2) Of the three out of door regions, in the one where underground parts are buried under, the development of stems and leaves as well as the yield of tubers is greatest, next the one wher the plants are left on the surface of the earth. Between those two regions, there arose a difference in the development of tops and at last was resulted the difference in the yield of underground parts, owing to many synthetic underground conditions, not only temperature, but also humidity et al.

(3) Of out of door regions, the low temperature region in the underground parts is inferior to the other two, both in the development of leaves and stems above ground and that of tubers underground, probably owing to the too low temperature underground or to the disparity between temperature above and underground. Plants as a whole showed a stunted abnormal phenomenon.

(4) The specific gravity of tubers yielded seems to be greater in the high temperature region within a green house.

III. We planted potatoes, making the main stems under ground long and let them grow in different place conditions underground, burying their lower half or one side. Thus we observed how they will bear tubers.

(1) In a region with different conditions between upper and lower parts, the upper half clearly yielded more tubers.

(2) In a region where one side was buried, the upper part produced pretty more tubers than the lower, but the same difference was seen between the both sides of the upper part.

(3) In a region where lower parts were buried, at the upper and lower parts, and in a region where one side was buried, at each norther and southern side of upper and lower regions, we took temperature of buried and no buried parts, and compared the yield condition of tubers among then. In that case, the yield of tubers, namely tuberization, varies, it is imagined, with the difference in environmental conditions of underground parts within the individual.

IV. We planted potatoes, making the soil conditions different between the two sides of underground parts of the same individuals, namely, a sandy loam and clay, and examined their way of taking tubers.

(1) A sandy loam is better than clay in the number and length of avariable stolons as well as in the weight and number of tubers. A sandy loam is probably more suitable to the yield of tubers than clay, in the synthesis of atmospheric and mechanical conditions.

(2) There is no difference in the specific gravity among those tubers produced in these two kinds of soil.

(3) The size of lenticels on the surface of larger in clay.

V. We arranged five regions differing in soil humidity according to the water level under ground and another region of dry (sprinkling water now and then) and observed how the growth of potatoes and the yield of tubers will differ among these regions.

(1) The growth of tops and the yield of tubers are both worst in the dry region (the amount of contained water about 30 %).

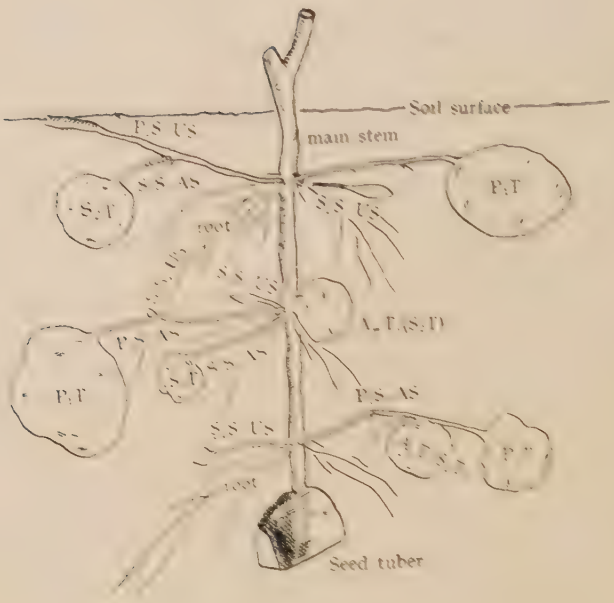
(2) In the regions with more than 40 %, the growth of tops has the tendency to increase with the increase of humidity. But in the yield of tubers, no striking difference is to be seen.

(3) In the yield of tubers according to tops, soil humidity of about 40–60 % seems to be best.

(4) The specific gravity of tubers is somewhat greater in the dry region, but there is no difference among the rest.

(5) In the development of lenticels on the surface of tubers, their size (diameter) becomes greater with thr increase of soil humidity.

VI. In the growth process of potatoes, a short day length treatment for 10–15 days before the differentiation of tubers clearly hastens tuber formation. The length of day light as a short day length condition is 8–11 hours.



AS	a.	Available stolon	Stolon
US	b.	Unavailable stolon	
P_1S	a.	Primary stolon (the first)	
S_1S	b.	Secondary stolon (the first)	
S_2S	c.	" (the second)	
S_3S	d.	" (the third)	
P_1T	a.	Primary tuber (the first)	Tuber
S_1T	b.	Secondary tuber (the first)	
S_2T	c.	" (the second)	
S_3T	d.	" (the third)	
AmT	e.	Axillary tuber (in main stem)	
AsT	f.	" (in stolon)	

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Studies on the Leaf Spot of Rice Plant*

(2) Histological observations of the invading process, formation of lesions and comparative observations with the blast disease

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(Received December 15, 1952)

The leaf spot disease of rice plant, caused by *Ophiobolus Miyabeanus* Ito et Kurib., is one of the most wide spread diseases in Japan. Especially in the sandy and peaty rice fields, it causes very serious damages and so number of investigations have been done with this disease, histological observations of lesions on leaves, the relation between the present disease and environmental conditions, that is, soil, fertilizer and climate, etc.

The sheath-inoculation method was used in these experiments. This new and convenient method has been firstly devised by Dr. M. Sakamoto[1], who used this to make reseaches into the nature of disease resistance of rice plant to the blast fungus. The writer previously reported in Japanese[2] with 18 sheets of photomicrographs, observations of invading process and the formation of lesion in many varieties. For these pourposes the new method was very usefully particularly for vital observations. In addition to these observations, the comparative observations between the present disease and the blast were done in this paper. There are many striking differences in character between them, and some of their distinctions were detected by means of this method.

The writer wishes to express his gratefull acknowledgment to Dr. Sakamoto under whose direction this study was made.

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I. Material plants and fungus

The seeds of many varieties of rice plant, sterlized by Uspulun and immersed in water for a week, were sown on May 7 (material A–a) and July 22 (material A–b) on Wagner's pots (1/20,000 h.) which were fertilized with ammonium sulfate 3 g, superphosphate of lime 4 g, and potassium chloride 3 g. On each pot three material plants were grown.

Two varieties of rice plant, Norin 21 and Aikoku 20, were sown on the nursery bed on April 28, and transplanted in early June on the sandy rice field which were normally fertilized (material B).

To study the effects of ammonium sulfate, to each pot of material A–a of several varieties was supplementarily added 10 g of it on July 28 (material C). The following table is shown to aid the understanding of material plants.

Table 1. Explanation of materials.

Material	Sowing	Transplant	Supplemental fertilizer	Varieties
A–a	May 7	pot	non	see Table 2
A–b	July 22	pot	non	
B	April 28	in early June rice field	non	Norin 21, Aikoku 20
C	May 7	pot	July 28	see Table 4

The fungus was cultured on the potato decoction agar medium containing 2 per cent of cane sugar. On this medium the aerial hyphae developed very well and the conidia were produced abundantly. However, in the course of a month, the conidia lost their ability to actively affect epidermal cells of the host. The blast fungus, *Piricularia oryzae* Cav., was cultured on rice culms and numerous conidia were found especially on their nods. As the virulence of the blast fungus is variable according to the kinds of culture medium, the author exclusively used only rice culm throughout the present experiments.

II. Method of inoculation and preparation of material

The sheath-inoculation — its details have been described by Dr. Sakamoto[1] was applied by the author as it was simple and convenient particularly for vital observations. For material, usually 10 inoculated sheaths were prepared in 2 Petri dishes. These Petri dishes were incubated in the dark underground room

which was kept at 23°–24°C in the course of experiments. The concentration of spore suspension was to be more diluted than that of the blast fungus because the present fungus grew more rapidly and branched more vigorously. Therefore, the lesions produced by each spore had the tendency to coalease together. The suitable suspension is that which contain 2 or 3 spores in one drop.

The incubation-period was changed according to the experimental purposes. Ordinarily it was shorter than that of the blast fungus. Some of the material pieces were immediately observed in intact conditions or photographed under microscope, and the others were fixed by diluted alcohol (20 per cent) and stored.

III. Results of the observations

To describe briefly the results of observations it was convenient to classify these lesions, each of them was formed by one spore into several types. The type might be determined by their development, the grades of break-down and coloration of cells, etc., but the author expediently arranged them in the following four types according to their development and coloration observed under microscope.

Type-A : the central aerea is affected severely and its sorounding zone changes its color to deep brown.

Type-B : all of the affected parts are brownish in color.

Type-C : no coloration occurs in the lesion (cf. Pl. No. 3)

Type-D : the number of affected and colored cells is less than about 10.

To give full details of the states of lesions, this classification was not sufficient and required more detailed explanation, for examples, the grade of coloration observed by unaided eyes, and of hyphal development in lesions. Sometimes, two or more types were formed in the same material piece, the reason for this may be noted later in this paper, but in most cases one or two were prevailing in number.

In applying this classification, the author carried out the following observations and their description will be given below.

Experiment 1. Observations in various varieties of rice plant

On July 20 (1st examination) and 28 (2nd examination), 17 varieties of material A-a which were incubated for 20 hours were observed. With the blast fungus they were incubated for 48 hours. Its results are shown in Table 2. In this table and the following two, the infection-grade was calculated according to the formula presented by Dr. Y. Takahashi.[3] For material pieces the outermost and the next sheaths were used.

Table 2. Observation in 17 varieties.

No. Varieties	Leaf spot diease							Blast disease			
	Grade of coloration(1)		Type of lesions(2)		Hyphal growth(3)		Development of lesion	Infection grade		Grade of coloration of cells(4)	
	1st	2nd	1st	2nd	1st	2nd	1st 2nd	1st	2nd	1st	2nd
1 Futaba	⫲	−	AB(5)	CA	⫩	±	=	6.2	2.7	±	±
2 Wasefukoku	〃	〃	A	AC	⫲	+	>	6.0	3.7	⫩	⫩
3 Norin 41	〃	±	AB	A	⫩	±	≫	5.0	2.9	−	⫩
4 Te-tep	〃	−	A	B	⫩	+	=	1.9	1.7	−	±
5 Hokuriku 11	〃	〃	A	C	⫲	+	⫞⫟	5.6	0.8	⫩	−
6 Fukubozu	⫲	〃	AB	C	+	±	⩽=	4.5	3.0	−	⫩
7 Asahi	〃	〃	BA	C	⫲	±	=	4.4	1.4	+	−
8 Lady Wright	〃	〃	A	AC	⫩	+	≫	3.6	3.5	±	+
9 Mêng-ku-tao(6)	〃	〃	A	AC	⫩	+	=	7.8	3.5	−	+
10 Kuan-yin-hsien(7)	〃	〃	A	AB	⫩	±	⩽=	1.8	1.3	−	+
11 Eiko	〃	〃	A	AC	⫩	±	=	5.6	3.0	⫩	+
12 Aikoku 20	⫩	〃	D	D	+	±	≫	3.3	1.8	−	±
13 Muikawase	〃	〃	C	C	+	±	≫	1.5	1.3	−	±
14 Karalath	〃	〃	AB	AB	+	±	≫	2.0	1.4	−	−
15 Norin 16	〃	〃	CA	C	+	±	⩽=	5.7	3.6	±	⫩
16 Norin 21	〃	〃	D	DC	+	±	=	4.7	1.5	+	−
17 Modan	〃	〃	A	B	⫩	±	⩽	2.1	1.6	−	−

Note. (1) observed by naked eyes. (2) lesion produced by one spore. (3) number of cells invaded by hypha from one appressorium, ⫲ more than 20, ⫲ morethan 10, ⫩ 10∼5, + 5∼2, ± one cell or only appressorium. (4) ⫩, more than half of invaded cells are colored, + 1/2∼1/4, ± few cells. (5) mainly A is observed. (6) 蒙古稻. (7) 觀音秈.

Experiment 2. Observations in the material B at various periods

Observations on the materials grown on the sandy rice field were made successively at various periods. In this field the present disease happened in early August, and did violent damages especially to Norin 21. On the contrary, the blast

Table 3. Observations at various periods with material B.

No.	Date	Leaf sopt disease						Blast diseas	
		Grade of coloration		Type of lesions		Hyphal growth(1)		Infection grade	
		N-21(2)	A-20(3)	N-21	A-20	N-21	A-20	N-21	A-20
1	July 16	⫩	⫲	AB	AB	10	5-10	1.9	2.5
2	〃 30	±	+	AC	AB	1-3	2-5	1.3	1.0
3	Aug. 6	−	±	AC	AB	1-2	2-4	0.9	0.9
4	〃 13	−	−	CB	AC	ap(4)	ap.	0.8	1.0
5	〃 20	−	±	CB	AB	〃	〃	0.6	0.5
6	〃 27	−	−	CB	CB	〃	〃	—	—

Note. (1) the number of cells in which hyphal growth is seen, hypha produced from one appressorium. (2) Norin 21. (3) Aikoku 20. (4) only appressorium is observed on a lesion.

did not occur. In this experiment, the outermost and next sheaths inoculated with both pathogens were used incubation for 40 hours. The results are shown in Table 3.

Experiment 3. The effects of the supplementarily added ammonium sulfate.

To observe the effects, five varieties of material C were used. Their 3rd and 4th sheaths from the outermost side were incubated for 16 hours with the leaf sopt fungus and 48 hours with the blast ones. The experiment was carried out on August 5, 9 days after the fertilizer had been added. Its results are shown in Table 4.

Table 4. The effects of supplementarily added ammonium sulfate.

No.	Varieties	Leaf sopt disease						Blast disease			
		Grade of coloration		Type of lesions		Hyphal growth		infection grade		Grade of coloration	
		Kont.	Treat.	Kont.	Treat.	Kont.	Treat.	Kont.	Treat.	Kont.	Treat.
1	Karalath	−	+	C	B	1-ap.	1 2	2 1	2 9	−	+
2	Yin-nien(1)	−	+	C	B	〃	2 3	4 4	3 0	+	±
3	Mao-tsu-tou(2)	±	+	CB	B	〃	1 2	3 5	3 7	+	+
4	Méng-ku-tao(3)	±	+	CA	BC	〃	1-ap	3 3	6 8	±	±
5	Danahara	−	+	C	BA	〃	1 2	1 3	57	−	±

Note. (1) 銀粘. (2) 帽子頭. (3) 蒙古稻.

From the above mentioned results, the following phenomena were able to be pointed out.

IV. Explanation of the results

1. *Process of infection of the leaf-spot fungus and degeneration of cells*

Firstly, the process of infection will be noted, though the previous tables do not show it. Eight hours after inoculation, terminals of germ-tubes swelled slightly. These became appressoria which are irregularly oblong. When the positions in which appressoria were produced were divided into the following three parts, (a) the intercellular parts, (b) the other parts of cells and (c) those parts

Table 5. The position of appressoria.

	a	b	c
Number of app and the percentage	242 75	62 19	20 6

which could not be known to belong (a) or (b), two-thirds of them appeared on the intercellular parts of epidermal cells. This observation was made with the material B incubated for 40 hours in late July, and its results are shown in Table 5.

After about 10 hour's incubation, appressoria made rents on these parts and spread invading hyphae through them (cf. Pl. No. 1). However, it rarely happened that though hyphae developed all over the epidermal tissues, there was neither appressorium nor, of course, affected cells.

As one spore produced ordinarily two germ tubes, it began to invade from two points in the early stage, but later sometimes the hyphae which had emerged from the same sopre branched in all directions and so let two or more small lesions collease to make large one. When these several appressoria which were produced from one spore attached their underlying host cells at various time after inoculation, many different stages of infection were induced and two or more types of lesion were formed simultaneously in the same material piece. Soon after the infection had ended, the contents of conidia usually decreased and they became empty.

In these cells which were directly invaded by hyphae or indirectly affected by their toxic substances before invasion, there were many types of cellular degeneration, such as picnosis of cytolpasm, granular and vacuolar degeneration, and coloration. The picnosis and vacuolisation were not so often, but affected cells showed always various granular degenerations according to their conditions. The young cells rich in cytoplasm collapsed and their contents showed irregular coagulation, while the old ones poor in cytoplasm showed small or fine precipitates or globules. This distinction was observed more clearly in the periodical examination (Experiment 2). In Plate No. 3 the granulation of cells is demonstrated. This material piece of Aikoku 20 incubated for 40 hours was selected from those of the material B on August 22. A great number of colorless granules filled up the affected cells in vital states, and after fixation numerous small crystals of calcium oxalate were sometimes observed. In the examination 6 of Experiment 2, it was very difficult to distinguish the affected area from normal healthy parts, because the precipitates were so fine and the affected cells were entirely colorless.

The grade of coloration of cells was variable ; the masses of deeply colored cells could be found as the lesions by unaided eyes, slightly colored ones were observed only under microscope. In many cases the contents of colored cells did not coagulate into so large as visible precipitates, and so they were colored alikely (cf. Pl .No. 4), some lesions had the coagulated granules which were colored in black or dark brownish in their cells (cf. Pl. No. 2). These cells were produced generally 3 or 4 days after inoculation, and at that time the material pieces were considerably decomposed. Therefore, to observe them under normal conditions

very young materials were to be used, for example, with the material B in the 1st examination of Experiment 2, these dark-brownish colored cells were found after 40 hours' incubation. The younger the tissues were, the faster and deeper the coloration. The cells which seemed to have almost empty contents were scarcely colored. Such changes of color seems to be determined between hosts and the pathogens. Even when two or more spores could not cause the invaded cells to be stained, in the same tissue, one spore sometimes was able to cause the coloration of them easily under the same conditions. The small fragments of the hyphae contained in the spore suspension produced the effects to color readily their host cells.

As the material plants grew, the lesions gradually lost their brownish color and at last they turned into Type-C. This discoloration was particularly rapid in Experiment 1. In the 1st examination, the grade of coloration was able to be classified by the naked eyes, but in the 2nd after one week their color was not distinguishable except only one variety. That is to say, the varieties belonging to Type-C increased in number. In the paddy field, this change took place somewhat slowly. Both varieties were colored on July 16. One, Norin 21, faded out after 3 weeks, and the other, Aikoku 20, after 4 weeks and then was faintly stained in the 5th examination. With the supplementarily fertilized materiales, the affected cells of all varieties similarly deepened their brownish color (cf. Table 4).

2. Behavior of hyphae and development of lesion

Invading hyphae, forming infection cavities (cf. Pl. No. 1), grew more or less within the intercellular spaces of epidermal cells before they broke into the host cells.

In the young cells, the hyphae became large in diameter and developed so vigorously that they filled the cells (cf. Pl. No. 2). But in the old tissues appressoria produced short and slender invading-hyphae and ceased to spread in the host cells. As the number of cells directly affected by hyphae decreased with the growth stage, the hyphal growth was at last not distinguished even in the cells on which appressoria were produced. This decrease in hyphal development was rapid with the material A-a, too (cf. Table 1 and Pl. No. 4).

Some of these hyphae penetrated directly from one cell to the next through the cell-walls, and others were composed of branches that spread through intercellular spaces to the next other ones[4]. Sometimes these running hyphae spread for a long distance without any branches which grew intracellularly.

With the materials belonging to Type-D, the lesions were limited to a few cells. As previously mentioned, the hyphal growth in the young tissues was so active that the lesions expanded, but the cells of the immediate vicinity of spread hyphae were deeply colored (Type-A or -B). And then the lesion ceased

[illegible]

[illegible]

6. Limestone Caverns and Pits in the Ross Island

[illegible]

The Western Ridge of the Ross Island Limestone is the southern continuation of Ridge 4 (Ridge 4 and 5 are separated by the Central Valley of Ridge 4). Ridge 6 is the highest of the Ross Island Ridges. The Ridge 6 limestone is well jointed and weathered. Pits and caverns are numerous. The Ridge 6 limestone is similar to the Western Ridge.

The western slope of the Ross Island limestone ridges is the southern continuation of Ridge 4 (Ridge 4 and 5 are separated by the Central Valley of Ridge 4). Ridge 6, therefore, the highest limestone ridge in the Ross Island Limestone ridges. The western slope of the Ross Island limestone is similar to the eastern one.

The eastern slopes of the Ross Island limestone ridges, except [illegible]

The eastern slopes of the Ross Island limestone ridges, except [illegible]

The western slopes of the Ross Island limestone ridges, except [illegible]

The western slopes of the Ross Island limestone ridges, except [illegible]

The western slopes of the Ross Island limestone ridges, except [illegible]

according to their cultural conditions, but the nature of maturing and growth habit etc., had some influences on this reaction. Therefore, the relation between many factors which have effects on this reaction must be studied in the further experiments.

Summary

In this paper, the author observed the process of infection and formation of lesion of the leaf spost fungus with many varieties by means of the sheath-inoculation method. The reaction of rice plant to the present fungus was studied, and comparative observations of it and the blast disease were made.

Reference

(1) M. Sakamoto, Sci. Rep. RITU., D **1-2** (1951) 15.
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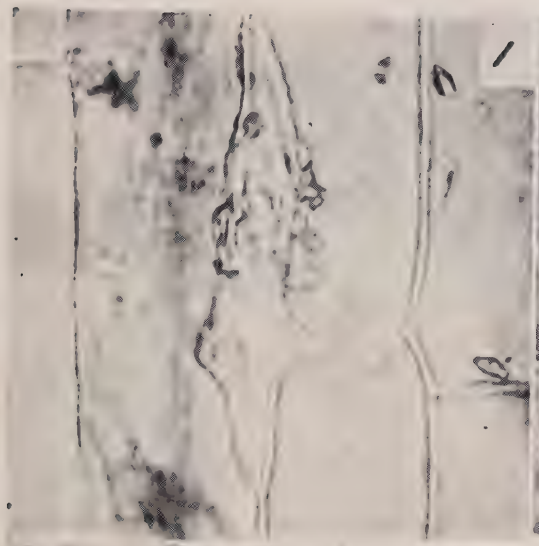
(4) E. C. Tullis, Jour. Agr. Res. **50** (1935) 81-90.

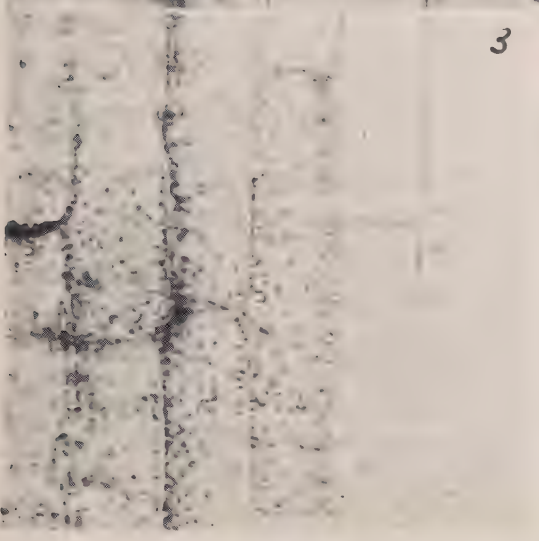
Explantion of Plate

No.	Material	Variety	Time of incubation	Date of exp.	Magnification
1	A—b	Aikoku 20	10h	Aug. 27	×1000
2	〃	〃	44h	〃	×540
3	B	〃	40h	Aug. 22	×720
4	A—a	Yin-nien	2 weeks(1)	Sept. 12	×96
5(2)	C	Mêng-ku-tao	48h	Aug. 5	×360

Note : (1) inoculated to the intact sheath ; (2) fixed with alcohol.

Plate 1.





Studies on the Soft-Rot Causing Bacteria of Vegetables Inhabiting in the Soil*

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I. Introduction

The soft-rot disease of vegetables, which is commonly caused by *Erwinia aroideae* (Towns.) Holl. in the field soil, is widely distributed in our country. For many years petsai (*Brassica pekinensis*) or cabbage cultivation have received heavy damages, especially after continuous warm and rainy days in early summer and early fall. At present there is no effective method for preventing the disease. However, information concerning the behaviours of a causal organism in the field soil may be required to find a control method for the disease.

There are numerous reports on the behaviours of phytopathogenic fungi in soil. Garret[1] (1944), in his recent monograph "Root disease fungi", outlined the previous knowledge in this field. However, there are only several reports on the behaviours of soilborne-disease bacteria in field soil.

Pathogenic bacteria introduced into soil must compete for space and nutrition and enter in predatory relationship with other soil micro-organisms. Thus the one may gradually decrease its activity, whereas the others may thrive and become a permanent resident in the soil. Such a trend may also be influenced in its transition by environmental conditions, effects of plant roots, and by antagonistic relations with other soil microbes. Definite evidences, however, have not yet been obtained experimentally.

Since 1950 the authors have been engaged in the investigation of the soft-rot causing bacteria of vegetables. They[2] have reported on the isolation procedures of the causal organisms from soil or diseased host plants. Herein is presented a classification of the causal bacteria as well as their seasonal variation in field soil.

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* The 84th report of the Institute for Agricultural Research, Tohoku University (1953).

II. Bacteriological study on the causal organisms

It has been reported that the soft-rot disease of vegetables in field soil is caused by *Erwinia aroideae*, *E. carotovora*, and *E. atroseptica*, etc. Since these species are very similar in their bacteriological characters, opinions diverge as to their classification. Birkinshaw *et al.*[3] (1930) reported that *E. aroideae* and *E. carotovora* are distinct species, because of their metabolic products of sugars differ from each other. Waldee[4] (1945) held the same opinion and cited Voges-Proskauer test for the criterion of both species. Erlord[5] (1941) stated that these two species showed different selorogical reactions. Takimoto[6] (1951), comparing many soft-rot causing strains with their physiological characteristics, concluded that since there were some strains, which might be classified as different species by their bacteriological characteristics and there were also many intermediate strains, they should not be considered different species. Peter *et al.*[7] (1952), studying the 12 strains isolated from chalk rot of yellow and pink callas, concluded that "There appears no justifiable basis for naming the calla rot bacteria as separate species : hence *E. aroideae* should be considered as a (usually "non gas forming") strain of *E. carotovora*." Leach[8] (1930) also asserted that many soft-rot causing bacterial strains should be considered a strain of *E. carotovora*.

Recently it was reported that among the gram-positive and gram-variable, spore-former, *Bacillus mesentericus*, *B. subtilis*, and *B. polymyxa*, etc., are capable of causing the soft-rot of vegetables. Jackson and Henry[9] (1946) isolated *B. polymyxa* from the soil collected from various localities in Canada, and all isolated strains caused soft-rot of potato tubers.

1. Materials and methods

The isolation of bacteria from soil and diseased materials was done as reported in the previous paper.[2] About 280 strains were isolated, and examined their soft-rot causing abilities by artificial inoculation test on sterilized carrot-slices.

Seventy percent of the isolates caused soft-rot of carrot. Of them 33 were chosen and subject to further bacteriological detection after rigorous check to assure purity. *E. aroideae*, identified by Dr. H. Muko, was used for comparison. The sources of isolates and the methods of isolation are given in table 1.

2. Experimental results

i) Pathogenicity

Inoculation test was performed by inserting a inoculum with a thin needle deeply into the tissue of carrot or petiole of petsai. Symptoms and development

Table 1. Sources of isolates and method of isolation.

Culture no. of isolates	Source of isolates	Method of isolation	Date of collection
			1951
1	*E. aroideae* named by H. Muko, isolated from petsai	—	—
9	Field soil, Rokugo, Sendai	(1)*	Jan.
10	〃	(2)**	〃
32	Rotted cabbage, Kogota, Miyagi prefecture	(3)***	June
34	〃	(3)	〃
44(1)	Field soil, Kogota, Miyagi prefecture	(1)	〃
44(2)	〃	(1)	〃
72	Field soil, Rokugo, Sendai	(1)	July
77	〃	(1)	Aug.
83	〃	(1)	〃
84	〃	(2)	Sept.
85(1)	〃	(2)	〃
85(2)	〃	(2)	〃
88	Soil, Mt. Azuma, Fukushima prefecture	(2)	July
89	Field soil, Shimoiwakawa, Akita prefecture	(2)	Aug.
91	〃	(2)	〃
97(1)	Field soil, Hanadate, Akita prefecture	(1)	〃
97(2)	〃	(1)	〃
101	Road soil, Akimiya, Akita prefecture	(2)	〃
106	Mountain soil, Akimiya, Akita prefecture	(2)	〃
127	Rotted carrot, market in Sendai	(3)	July
139	Petsai, field of Tohoku Univ., Sendai	(3)	〃
152	Field soil, Takeya, Miyagi prefecture	(1)	Sept.
154	〃	(1)	〃
156	Field soil, Fukudamachi, Sendai	(1)	〃
181	〃	(1)	〃
191	〃	(2)	Oct.
199	〃	(2)	〃
$H_{(1)}$	Assigned from Hokkaido Agr. Exp, Sta. (isolated from petsai)	—	—
$H_{(2)}$	Assigned from Hokkaido Agr. Exp. Sta. (isolated from Rutabaga)	—	—
237	Field soil, Higashianiwa, Iwate prefecture	(2)	Nov.
238	Field soil, Iwate Agr. Exp. Sta., Morioka	(2)	〃
269	〃	(2)	〃
271	〃	(2)	〃

*(1) Direct isolation from soil.
**(2) Indirect isolation from soil.
***(3) Direct isolation from diseased plant.

of lesions were examined after 24–48 hours incubation at 30°C. All isolates under test showed a water-soaked appearance, and caused a softening and destruction of tissue. Softening was observable within 5–6 hours after inoculation. Excepted for Nos. 10, 237, 238, 269, and 271 most strains produced no gas bubbles in the water-soaked portion.

(ii) Morphology (table 2)

Thirty four stains were divided into two groups, viz., short rod (29 strains) and long rod (5 strains). The former was gram-negative, non spore-former, and varied from 1.2 to 2.8 μ in length and from 0.4 to 1.1 μ in width. The latter

was gram-variable, spore-former, and varied from 2.9 to 4.4 μ in length and from 0.7 to 1.3 μ in width. Thickly walled, ellipsoidal spores were freely formed apart from the sporangia after 48–96 hours incubation.

All of the isolates were actively motile. They were divided into two groups by their different arrangements of flagella. As shown in table 2, gram-negative, short rods had 2–6 peritrichous flagella, and gram-variable, spore-former had long

Table 2. Bacteriolological characteristics of the isolates.

		No. 9 and other 27 isolates	No. 127	No. 237 and other 4 isolates
Morphology	Morph	short rod 1.2–2.8μ×0.4–1.1μ	short rod 1.3–2.2μ×0.6–0.9μ	long rod 2.9–4.4μ×0.7–1.3μ
	Arrangement	single, seldom pair	single, seldom pair	single, seldom pair
	Flagella	peritrichous (2–5)	peritrichous (3–6)	peritrichous(many)
	Gram-stain	—	—	variable
	Spore	—	—	thick-walled, ellipsoidal, freely formed
Cultural characteristics	Agar plate	circular, entire, white, glistening	circular, entire, white, glistening	effused on entire surface, inconspicuous lobed
	Agar slant	filiform, white, glistening	filiform, white, glistening	growth scanty, effused on surface
	Agar stab	uniform growth	uniform growth	uniform growth
	Peptone water	moderate	pericle, strong	scanty
	Usinsky's media	moderate	pericle, strong	no growth
	Conn's media	no growth	pericle, strong	no growth
Physiological characteristics	Gelatine stab	infundibiliform liquefaction	—	—
	Litmus milk*	A. C. R.	A. C. R.	A. P. C. R.
	Reduction of nitrate	+	+	−
	Formation of H_2S	+	+	−
	Diastatic action	−	−	+
	Fermentation of sucrose**	A	A. G	A. G
	Fermentation of lactose	A	A. G	A. G
	Fermentation of glucose	A	A. G	A. G
	Fermentation of glycerine	A	A. G	A. G
	Indol formation	−	+	−
	Methylred test	+	±	−
	Voges-Proskauer test	−	±	±
	Koser's citrate media	+	+	−
	Reduction of methylen-blue	±	+	−
	Formation of ammonia	+	+	−
	Catalase	−	+	+
	Culture number of the isolates similar to the above	1, 32, 34, 44(1), 44(2), 72, 77, 83, 84, 85(1), 85(2), 88, 89, 91, 97(1), 97(2), 101, 106, 139, 152, 154, 156, 181, 191, 199, $H_{(1)}$, $H_{(2)}$,		10, 238, 269, 271

* A : acid formation, C : coagulation of casein, P : peptonization, R : reduction of litmus.

** A : acid formation, G : gas formation in Durham tube.

peritrichous flagella, grown thickly around the rod.

(iii) Cultural characteristics (table 2)

Appearance on agar and broth cultures of 29 gram-negative, short rods were in agreement with the description of *E. aroideae* and *E. carotovora* in Bergey's Manual. The other five isolates were different from the 29 strains in cultural characters, as shown in table 2.

(iv) Physiological characters (table 2)

(a) Relation to oxygen. This was examined by the growth in agar stab culture and in a Durham tube containing nutrient broth. All of the isolates were facultative anaerobes. Nos. 10, 127, 139, 181, 237, 238, 269, 271, $H_{(1)}$, and $H_{(2)}$ caused cracking of the agar medium and Nos. 10, 127, 237, 238, 269, and 271 produced gas in Durham tubes.

(b) Liquefaction of gelatine. Liquefaction of gelatine was examined by means of stab culture of nutrient gelatine. Gram-negative short rods, except No. 127, produced a rapid, infundibiliform type of liquefaction. No. 127 did not liquefy gelatine even within 10 days. Five gram-variable isolates failed to liquefy gelatine within 10 days incubation.

(c) Reaction to carbohydrates. Diastatic action : This was examined by iodine test (a saturated solution of iodine in 50 percent alcohol) after different periods of growth. Most of the cultures hydrolyzed no starch after two days incubation.

Fermentation of sugars and carbohydrates : Fermentation by bacteria was tested on Barisikov-nutrient solution, which contained one percent of sugar or glycerine ; a Durham tube was used for detection of gas production. Acid formation was also detected by the discoloration of bromthymolblue added to nutrient solution.

As shown in table 2, all of the isolates produced acid from lactose, sucrose, glucose, and glycerine, but 29 gram-negative isolates produced acid very slowly especially in glycerine-containing media. The ability to produce gas from carbohydrates differed in the respective isolates. Among gram-negative isolates only No. 127 readily produced gas from the carbohydrates tested. Five gram-variable isolates produced gas on all of the carbohydrates tested.

(d) Action on litmus milk. Action on litmus milk was observed after 2, 4, 7, 10, 14, and 21 days incubation, respectively. On litmus milk, acid formation, coagulation and digestion of casein, and reduction of litmus were observed. The transitional changes are shown in table 3 as A, C, P, and R, respectively. The isolates were divided into two groups. Nos. 10, 237, 238, 269, and 271 were involved in ACPR group and the other isolates in ACR groups. One isolate (H_1)

Table 3. Comparison of the isolates with already

		E. aroideae (Towns.) Holl.	No. 154	*E. carotovora* (Jones) Holl.
Morphology	Size	0.5×2-3μ	0.7×1.8-.2μ	0.7-0.8×1.5-5.0μ
	Morph	short rod	short rod	short rod
	Arrangment	single, seldom pair	single, seldom pair	single, seldom pair
	Flagella	peritrichous	peritrichous(2–6)	peritrichous
	Gram-stain	—	—	—
	Spore	—	—	—
Cultural characteristics	Agar plate	circular-amoeboid, white, glistening	circular, white, glistening	circular, white, glistening
	Agar slant	filiform, white, glistening	filiform, white, glistening	filiform, white, glistening
	Peptone broth	strong	moderate	pericle, strong
	Usinsky's broth	strong	moderate	strong viscid
	Conn's broth	—	no growth	—
Physiological characteristics	Gelatine stab	liquefy infundibiliform	liquefy infundibiliform	stratiform liquefaction some strains slow
	Litmus milk	A. C. R.	A. C. R.	A. C. R.
	Nitrate reduction	+	+	+
	Formation of H_2S	+	+	+
	Fermentation of glucose	A	A	A. G
	Fermentation of sucrose	A	A	A. G
	Fermentation of lactose	A	A	A. G
	Fermentation of glycerine	A	A	A. G
	Diastatic action	−	−	−
	Indol formation	−	−	−
	M. R. test	−	+	+
	V. P. test	+	−	−
	Koser's citrate media	+	+	+
Relation to oxygen		facultative anaerobe	facultative anaerobe	facultative anaerobe
Temperature relation	min.	−	−	−
	opt.	35°C	34°C	25–30°C
	max.	41°C	40–43°C	38–39°C
Pathogenicity		+	+	+

* Described according to Bergey's Manual.

showed no coagulation of casein during the incubation period.

(e) Formation of hydrogen-sulphide. The isolates were grown on agar media containing lead acetate. Hydrogen sulphide formation was indicated by the dark coloration of the media along the stab line. Five gram-variable isolates produced no hydrogen sulphide, whereas the others did.

(f) Reduction of nitrate. Reduction of nitrate to nitrite was examined by the usual methods. Five gram-variable isolates reduced nitrate to nitrite, and the

known soft-rot causing bacteria.

No. 127	**B. polymyxa* (Praz.) Migula	No. 269
0.8-0.9×1.3-2.2μ	0.6-1.0×2.5-6μ	0.8-1.2×2.9-5.0μ
short rod	long rod	long rod
single, seldom pair	single or pair, seldom chain	single or pair
peritrichous (3-6)	peritrichous	peritrichous (many)
—	variable	variable
—	ellipsoidal, wall thick, and freely formed	ellipsoidal, wall thick, and freely formed
circular, white, glistening	thin, inconspicuous lobed, effused on suface, round, whitish and tough	effused on entire surface, inconspicuous lobed, tough
filiform, white, glistening	growth scant, to moderate, indistinct, whitish	growth scant, effused on surface
pericle, strong	scanty	scanty
strong	no growth	no growth
strong	—	no growth
no liquefaction	no liquefaction	no liquefaction
A. C. R.	A. P	A. C. P. R.
+	+	+
+	−	−
A. G	A. G	A. G
A. G	A. G	A. G
A. G	A. G	A. G
A. G	A. G	A. G
−	+	+
+	−	−
±	−	−
±	+	±
+	−	−
facultative anaerobe	facultative anaerobe	facultative anaerobe
	−	−
34°C	30°C	37°C
43°C	43-45°C	43°C
+	liquefy the pectin and hemicellulose	+

others reduced nitrate to nitrite and further to ammonia.

(g) Production of ammonia. Production of ammonia was detected by dropping Nessler's reagent in peptone broth. Except for five grain-variable isolates, the majority showed ammonia formation.

(h) Reduction of methylenblue. Reduction of methyleneblue added to the peptone-broth culture containing phosphate and glucose was examined by means of its discoloration. After 24 hours incubation, methyleneblue was added, and

further incubated for 24 hours at 37°C. Five gram-variable isolates did not reduce methyleneblue, but the others reduced it very slightly.

(i) Indol formation. Peptone, confirmed previously to contain tryptophan, was used for preparing broth. After incubation, indol was detected by the Ehrlich-Böhme's method. It was found only in the culture of No. 127.

(j) Methyl-red test. After incubation methyl-red solution was added to peptone broth containing phosphate and glucose, and the reaction was examined. Twenty nine gram-negative isolates showed positive reaction ; the others were negative.

(k) Acethylmethylcarbonyl production. After incubation in peptone broth, containing phosphate and glucose, 40 percent solution of potassium hydroxide was added and the reaction was observed. Gram-negative isolates gave almost negative reaction. Nos. 10, 127, 237, 238, 269, and 271 gave slightly positive reaction.

(l) Growth on Koser's citrate medium. Five gram-variable isolates failed to grow on this medium, but the others grew quite well.

3. Comparison of the isolates under test

Among the soft-rot causing bacteria isolated from the soil, there were two groups of different strains. The one is gram-negative, non spore-forming, peritrichous, short rod. The other is gram-variable, spore-forming, peritrichous, long rod. These two groups are obviously different in cultural and physiological characteristics as shown in table 2. According to Bergey's Manual, the former agrees with *Erwineae* and the latter with *Bacillaceae*. Among the isolates belonging to *Erwineae*, there were two physiologically different groups. The one coincides with *E. aroideae*, identified by Dr. H. Muko, while the other differed in certain physiological characters, especially in gas formation on carbohydrate-containing media.

4. Comparison of the present isolates with the previously reported species

As mentioned above the isolates were divided into three groups. Nos. 154, 127, and 269 were taken as representatives of the respective groups and these were compared with the bacteria, which had already been reported as soft-rot causing bacteria in literature. According to Bergey's Manual the criterion for the distinction between *E. aroideae* and *E. carotovora* is based on the gas production on various carbohydrate-containing media. As shown in table 3, Nos. 154 and 27 other non gas-producing strains correspond with *E. aroideae* in most characters so far examined. Concerning the results of Voges-Proskauer test and methyl-red test, they indicated the similar reaction to *E. carotovora*, and since they failed to

produce gas on sugar-containing media, they should be identified with *E. aroideae* (Towns.) Holl.

Isolate No. 127 is similar with *E. carotovora* in many characters, but differs in indol production and in the capability of liquefying gelatine. Takimoto[6] (1951), in his study on the soft-rot causing organisms distributed in Japan, reported "C strain", which in many characters differed from both *E. carotovora* and *E. aroideae*. Our strain also differed from C strain in capability of liquefying gelatine and of digesting milk casein, but were similar in indol production, gas production from carbohydrates, and in the capability of growing on Conn's media. Paying no attention to pathogenicity to vegetables, it would be considered as *Escherichia freundii* (Braak) Yale. Since the authors considered pathogenicity to vegetables and gas production on carbohydrate-containing media as important criteria for the classification, No. 127 should be regarded as a strain of *E. carotovora* (Jones) Holl.

No. 237 and four other strains are similar to *Bacillus polymyxa* in various characters, but differ in the capability of coagulating milk. Although Breed *et al*[12]. (1948) reported that *B. polymyxa* could liquefy pectin and hemicellulose, they did not mention about its pathogencity to vegetables. Jackson and Henry[9] (1946) reported that *B. polymyxa*, isolated from soil of various localities in Canada, caused soft-rot of potato tuber under both experimental and field conditions. As our isolates are quiite similar to those reported by Jackson and Henry, they may be designated as *B. polymyxa* (Praz.) Migula.

To sum up, most of our pathogens were found to belong to *E. aroideae* and a few to *E. carotovora* and *B. polymyxa*. Since the first named species could be isolated from almost all of the materials collected from various localities in the Tohoku region, it might be the most common soft-rot causing organism. The strains belonging to *E. carotovora* were isolated only from the rotted carrot. *B. polymyxa* was isolated only from the soils obtained from the vicinity of Sendai and Morioka, but it remained uncertain whether it might be capable of causing vegetable rot under field conditions.

III. A seasonal variation of the soft-rot causing bacteria in the field soil

The few informations hitherto known on the behaviours of the soft-rot causing bacteria in field soil are almost confined to problems of the existence or longevity in field soil. Patel[13] (1929) demonstrated that eight bacterial pathogens, including *Pseudomonas tumefaciens*, *Ps. phaseoli*, and *Bacillus carotovorus*, etc., were able to overwinter in sterilized soils in test tubes. Leach[8] (1930) reported that *E. carotovora* is able to overwinter in Minnesota field soil. Vorankewich[14]

(1948) reported that *E. aroideae* lived in sterile clay soil for nine months under low temperature condition. Okabe[15] (1948) reported that *E. aroideae* survives for more than 40 months in field soil.

As mentioned above, it may be said that *E. aroideae* is able to live for a long time. In this respect Burkholder[16] (1948) suggested that *Agrobacterium tumefaciens. E. carotovora,* and *Pseudomonas solanacearum* "have an extensive host range and may be living on the roots and crowns of various plants instead of in a saprophytic state." Valleau and his associates[17] (1944) demonstrated that *Pseudomonas tabaci, Ps. angulata,* and *Xanthomonas vesicatoria* can survive on the roots of various plants and thus overwinter.

These facts present quite interesting problems to the studies of the life history of soil-borne pathogen. From the practical standpoint thus may be reconsidered from the view of crop-rotation as a means of preventing the hibernation of pathogen in field soil.

From June 1950 to November 1951 we investigated on the seasonal trend in the activity of soft-rot causing bacteria in field soil.

1. Seasonal variation in the activity of soft-rot causing bacteria in field soil

(i) Experimental field

Investigation was made on two experimental fields (A and B), separated about 1 kilometer from each other and situated in the vicinity of Sendai. Both fields consisted of sandy loam, but B was more calyey and rich in humus (by Tiulin method). Every year the petsai cultivation in these fields has suffered from the severe outbreak of soft-rot disease. In 1950, field A was flooded twice in August and September.

Successive planting in both fields during the experimental period were as follows :

Field A : potato (April—middle July, 1950)—petsai (11th August—early Nov.) —wheat (late Sept., 1950 – middle June, 1951)—soybean (middle June—late Dec., 1951) ; Field B : potato (April—middle July, 1950)—petsai (10th August—late Nov., 1950)—fallowing—potato (April—late July, 1951)—petsai (5th August—late Nov., 1951).

(ii) Materials and methods

Sampling of soil was made once or twice a month, as shown in table 4, during the experimental period. Soil was taken from a depth of 5 cm under the surface between the plants on the ridge by means of a sterilized glass cylinder.

Confirmation of an existence of pathogenic bacteria in soil under test and evaluation of their densities were made by means of the two procedures described

Table 4. Seasonal variation in percentage of the rotted carrot-slices inoculated with soil suspensions of different dilutions. (incubation temperature : 30°C)

Date of sampling	Experimental field	Percentage of rotted carrot after 48 hours incubation				Percentage of rotted carrot after 96 hours incubation			
		Dilution of soil suspension				Dilution of soil suspension			
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-1}	10^{-2}	10^{-3}	10^{-4}
1950 June 14	A	100	100	100	100	100	100	100	100
	B	100	100	100	100	100	100	100	100
July 18	A	0	0	0	0	100	100	33	0
	B	0	0	0	0	100	100	67	33
Jnly 31	A	0	0	0	0	20	0	0	0
	B	0	0	0	0	0	0	0	0
Aug. 8	A	0	0	0	0	20	0	0	0
	B	0	0	0	0	0	0	0	0
Aug. 18	A	0	0	0	20?	40	0	0	20?
	B	60	0	20?	20?	60	0	20?	20?
Sept. 5	A	0	0	0	0	40	0	0	0
	B	0	0	0	0	0	0	0	0
Sept. 12	A	0	0	0	0	20	0	0	0
	B	0	0	0	0	20	0	0	0
Sept. 28	A	60	40	20	0	60	40	20	0
	B	20	0	0	0	20	0	0	0
Oct. 24	A	20	0	0	0	80	60	40	0
	B	0	0	0	0	20	20	20	0
Nov. 14	A	10	10	20	0	10	10	20	0
	B	30	30	30	0	40	80	30	0
Dec. 9	A	100	0	30	0	100	20	30	0
	B	30	0	0	0	80	40	60	0
1951 Jan. 19	A	100	20	0	0	100	70	60	30
	B	0	20	20	0	70	50	60	20
Mar. 17	A	0	0	0	0	70	10	10	0
	B	0	0	0	0	40	40	30	0
Apr. 16	A	0	0	0	0	0	0	0	0
	B	0	0	0	0	40	40	10	0
May 15	A	40	0	0	0	70	10	0	0
	B	0	0	0	0	80	0	10	20
June 12	A	0	0	0	0	30	0	0	0
	B	10	0	0	10	50	0	0	0
June 28	A	0	10	10	20	20	20	40	30
	B	0	30	10	0	10	90	10	10
July 12	A	0	50	30	20	0	70	40	30
	B	30	20	30	0	30	20	50	30
July 24	A	10	10	0	0	20	10	0	0
	B	20	0	10	10	20	0	10	10
Aug. 27	A	—	—	—	—	—	—	—	—
	B	0	0	0	0	0	0	0	20?
Sept. 27	A	20	0	0	0	30(10)*	10	10	0
	B	10	0	0	0	20	20	0	0
Oct. 6	A	10	10	30	20	80(40)	30(20)	60	30
	B	20(10)	20	0	0	50(50)	60	10	0
Oct. 16	A	30	0	0	0	50	30	20	0
	B	40	20	0	0	90(10)	40	10	0

? indicates a rotting probably caused by using an already affected, if not observable, test-material.

* The number in parenthesis indicates the percentage of rotted carrot by soil fungi.

elsewhere[2]. The results thus obtained are shown in table 4.

(iii) Results

According to the results given in table 4, the proportion of rotted carrot in every experiment showed seasonal variation, but were similar in both fields in their trends. At the beginning of the investigation, middle June in 1950, the inoculated carrot-slices rotted within 48 hours incubation and showed higher proportion of rotting, thus indicating a dense distribution of the pathogen in soil. In the second sampling, middle July, soft-rot of slice did not occur within 48 hours incubation and the percentage of rotted slice decreased even after 96 hours, thus indicating a less dense distribution of the pathogen in soil. In late July it decreased sharply and this continued until middle September. Then, in late September, when the characteristic symptoms of soft-rot disease began to appear on the outer leaves of petsai near the ground, it suddenly increased and attained gradually to the highest value at the middle of January in 1951. Since then it decreased gradually and remained in low values from March to middle of June. Then it again increased from late June to middle July as during the previous year. In summer it decreased rapidly as in the year of 1950.

2. Seasonal variation in the numbers of gram-negative bacteria in soil, examined by a plate-count method

(i) In a prevoius paper[2] we reported the procedure for isolating soft-rot bacteria from soil samples and rotted vegetables by using a plate culture of modified Drigalski's medium. Since crystal violet, contained in this medium, may inhibit the growth of gram-positive bacterial group, the numbers of bacterial colonies which appear on the medium may be roughly taken as a possible indication on those of gram-negative bacteria including the soft-rot group. Thus the investigation on the seasonal variation of gram-negative bacteria in field soil was carried out in accordance with that described in the preceding chapter.

One cubic centimeter of soil suspension of a given dilution (orders of dilution usually employed were 10^{-3}, 10^{-4}, and 10^{-5}) was poured into a Petri-dish with an aliquot quantity of melted, modified Drigalski's medium. After 48 and 96 hours incubations at 30°C respectively, the numbers of bacterial colonies developed on or in the medium were counted. The results are shown in table 5.

(ii) Results

The trends in the numbers of gram-negative bacteria in both field soils, as shown in table 5, indicate that they also varied seasonally corresponding to those of the soft-rot bacteria described in the preceding chapter. The numbers of gram-negative bacteria, maintained considerably higher values during July,

Table 5. Seasonal variation in the numbers of gram-negative bacteria appeared on the modified Drigalski's media (per 1 g of wet soil)

Date of collection	Soil A			Soil B		
	Water content of soil %	Numbers of bacteria		Water content of soil %	Numbers of bacteria	
		after 48 hours	after 96 hours		after 48 hours	after 96 hours
1950		$\times 10^{-5}$	$\times 10^{-5}$		$\times 10^{-5}$	$\times 10^{-4}$
July 3	—	45.0	—	—	11.0	—
July 18	15.0	24.0	—	18.1	2.4	—
July 31	25.0	2.6	—	25.8	0.7	—
Aug. 3	—	0.6	—	—	0.4	—
Aug. 18	16.6	0.3	0.4	19.3	0.0	0.0
Aug. 22	—	—	—	—	0.8	1.3
Sept. 5	22.4	1.4	—	22.6	1.8	—
Sept. 12	21.8	6.2	8.6	23.9	1.1	2.1
Sept. 28	—	2.7	3.4	—	8.3	13.0
Oct. 24	24.0	5.8	7.0	25.8	2.1	5.9
Nov. 14	24.8	28.0	51.4	26.2	77.0	188.0
Dec. 9	31.2	17.0	23.8	30.6	120.0	183.0
1951						
Jan. 18	30.0	7.0	13.3	34.4	74.0	160.0
Feb. 15	24.0	39.0	52.8	23.3	14.0	27.7
Mar. 17	22.4	3.4	7.4	19.8	12.0	20.1
Apr. 16	20.2	10.0	17.0	19.2	12.0	17.7
May 15	27.0	21.0	39.9	26.8	—	—
June 12	18.7	49.0	58.8	19.4	6.1	17.9
June 28	16.1	5.7	7.1	16.9	7.6	11.0
July 12	—	3.2	3.8	—	18.0	22.0
July 24	—	—	—	—	—	—
Aug. 8	—	1.0	1.2	—	1.6	3.9
Aug. 28	—	—	—	16.8	2.4	3.8
Sept. 11	29.0	4.2	13.5	22.8	4.5	11.1
Sept. 21	24.9	18.0	26.2	24.6	2.7	12.0
Oct. 16	26.0	10.0	15.0	26.8	4.3	4.6

rapidly decreased toward the hot season until the lowest value which was reached in middle August. Then from early September they increased gradually and reached the maximum in December. In the next year they decreased during spring and then again began to increase toward middle June. During the hot season they maintained lower values and suddenly increased in early September in a way similar as those in the preceding year.

To sum up, it may be said that the seasonal trend in the number of the soft-rot bacteria in field soil indicates a similar tendency, as a whole, to that of gram-negative ones. It may be also pointed out that the maximum or higher values of the bacterial numbers in soil coincide with outbreak of the disease in early summer (soft-rot of cabbage or potato) and early fall (soft-rot of petsai). These facts may suggest certain relationships between the outbreak of the disease and activities of the pathogens in soil. The lowest values which occur in the hot summer season seem to be due to the high sensibility of the soft-rot bacteria to

dryness. However, the cause of the higher values of bacterial numbers obtained during the cold season have not been explained. To obtain definite evidence about the above mentioned relationships, further investigation on various factors, both environmental or biological in relation with the behaviours of pathogenic bacteria in soil are necessary.

IV. Summary

About 280 bacterial strains were isolated as the responsible organisms to the soft-rot disease of vegetables from rotted petsai or carrot and from soil samples collected from various localities of Tohoku district (northern part of Japan). Of them about 220 strains were proved to be capable of causing soft-rot by artificial inoculation. In the present investigation 34 strains among them were examined as to their bacteriological characters.

1. Most of the 34 strains were found to belong to *Erwinia aroideae* (Towns.) Holl., and a few to *E. carotovora* (Jones) Holl., and *Bacillus polymyxa* (Praz.) Migula. The first named species seemed to be the most prevailing soft-rot organism, while the second was isolated only from rotted carrot. *B. polymyxa* was isolated only from the soils in the vicinity of Sendai and Morioka, for its capability to cause vegetable rot under field conditions remained uncertain.

2. From June 1950 to October 1951, the seasonal variations in the activity of the soft-rot bacteria in field soil were examined by means of the carrot-slice method[2]. During the same period a seasonal trend in the numbers of gram-negative bacteria including the soft rot ones was traced by the plate-count method using a modified Drigalski's medium.[2] Both results (tables 4 and 5) coincided in the essential points : a higher activity of the soft-rot bacteria in field soil was found to correspond to a relative abundance of gram-negative ones, especially in the seasons of early summer and early fall, respectively, when the present disease usually outbroke. Both showed the lowest values in the hot season when the disease did not occur. The reason why the soft-rot bacteria as well as gram-negative ones showed such a seasonal variation in field soil is still unknown.

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Problems of Japanese Agricultural Co-Operative Association*

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I

To make critical remarks upon the agricultural co-operative association by the real situation, first we have to understand the association at its fundamental principles. Of course the agricultural co-operative association is an organic body of co-operative system. It has not entirely lost the specific nature of it's original function though it takes place in capitalistic society based on individual liberty. However it is not able to construct an ideal society on thoroughly organized co-operative system every where dogmatic devotees of the corporation want. It is a circle established in the capitalism to meet the ideology of the capitalistic society and it is never against the capitalism.

In the abstract the co-operative association is a power of number in a mass or an aggregation in the derivation. Each member of the association has only little power in unsystematic composition, meantime each organized one for decided purposes, makes greater power than simpl arithmetic sum of the numbers. The latter big power is natural as it is found in any country and in any age so that it seems rather superhistoric. In the ancient ages or in olden times, generally in the period with undeveloped techniques, the human labour power largely demanded directly for production as like as co-operatively organized. Simply in the medieval and in the modern ages the increased productive output shows us that the co-operative labour to evergrowing products. Human society always have had power of numbers for its own use.

The co-operative system of the numbers does not appear by simple corporation

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while any other natural or productive power is not found being abstractive and simple one itself in our society. The co-operative organization in the ancient ages was social to sustain the people who were occupied at not-specialized works : For instance free citizens of the leading class took the organic work of slavery for production. In modern ages the co-operative or productive labour of number power was esteemed worthy for capitalistic production even at the time when the machines were not yet popularly available to save the labour. As a matter of fact at factory the labour power was still used too. Being superhistoric at the substance expounds a theory of that the co-operative system took historical and social form for the power of number. Coming up to see the system, if we either put the accent merely on the natural force of labour of numbers, we shall pull about it missing its right sociality, and or diverting to only emphasized social meaning, we shall fail to count real effects of the system itself being critisezed too sharply as of excessively better or worse estimation of its ability.

Now we have to, not pursuing a romantic idea with only natural characters, make it out right oriented and composed by means of strictily real and social figures. The agricultural co-operative association is also one of such incorporated organization that shall be analized and criticized in this spot.

II

The agricultural co-operative association was established as the greatest corporation in farm villages in Japan descending from the Sangyokumiai (The Industrial Corporation) and Nogyokai (The Agricultural Association). Both were similar to the first one but existed before the second-world-war-end. The Agricultural Co-operative Association Law (1947) contains as the first article, the following : The association shall, in accomplishing its purpose to promote advancement of the farmers' corporation and the agricultural production with improvement of economic-social condition of the farmers, for it helps the national economics to progress. This farmers' co-operative association is for the small scale and poor farmers, most of them is hardly selfsustaining owner-operator arisen since the inauguration of the Farm Land Adjustment Law (1946) and the Owner Operator Establishment special Measurement Law (1946) after the war was over. By the law masters of these farmhouses and their field labourers became competent to apply membership of the organization. Anyhow it includes large people of the postwar small holding farmers. I think this fact in which the farmers join at the organization is important.

That the agricultural co-operative association was established for the self-sustaining poor farmers arisen after the land revolution, distinctively shows us the essential character of one of the corporation, however, in an opposite viewing

our peasants' circle made an available association using natural force of the system. Therefore the said selfsustaining poor farmers who were not organized systematically could not be able to increase the production and to have their economic and social status advanced aloft, meanwhile the systematic organization was making a force to really do that for them. Consequently the movement was expected because of the national economy pushed for developing by the joint farmers. In the original the Japanese farmers were mostly selfsustaining, accordingly it has not changed the selfsustaining quality to meet the commercial economy, but in fact being always touched by the market, in the contradicting relations they were often about falling down together to collapse. In the agricultural history after the Meiji era many instances were found so that the poor farmers largely dispossessed of the land running in grievous debt through channel of usurers' or merchants' investments like as story of the farmers' fall. The Sangyokai (The Industrial Corporation) existed before the war took the farmers under protection from the fall in the prodictive relation with the landownership. Although it kept the farmers safely remain apart from the usury and the merchants capital just in the days prior to the Japanese capitalism, and it rather took itself in the more capitalistic market and finally it made the national market developed for the capital itself. There was a role played by the farmers' incorporated organization in our commercialised economy. Every agricuatral co-operative association is one of the co-operative system for the farmers though each of them is poor and small scale farm and accordingly in their community the merchants' or usurers' investments were still operating. There occurred a big change in the productive relation with our village community. The enforcement of the Farm Land Adjustment Law gave the landownership big change in the villages, neverthless the poor farmers did not have themselves rapidly rose up for the radical reform of their farming, otherwise preponderant landowner's power was pushed away from the village. In such a region of rice farming, there landowners were mostly leading upon the share-cropper and the tenantry over 90%, with 10% owner operator before the execution of the law. Afterwards almost all of them became the owner operator over 90%. In the spot concerning the land possesion, the old owners' predicament on the unfavoured ground was sinking down in social relation when the agricultural co-operative association was established.

In the function of the agricultural co-operative association in the corporation system, the poor farmers were more directly combined with the capitalistic economy rather than in the Sangyokumiai the landlords pushed them for the similar finance. The co-operative association expressed the written purpose engaged in farm production promoting that means more worthy cropping in the marketable economy settled on quite independent situation. If they grow up the

selfsustaining crops to earn themselves on the stabilized field where nor starvation had ever occured and neither materials also had contributed for charity's sake. That is cause raised the article following the starting phrase as ".....it helps the national economy to progress." Because of the corporation has the purpose engeged in the farm production to elevate their status in the economic and social circumstances entirely independent from the long lasted feudalism.

Of course the commercial economy is based on the national economy what can not make any advance in natural or selfsustaining economy departed from current market. Thereupon the purpose of the agricultural co-operative association is to join farmers after the Land Reform to national economy efficiently on the co-operative system that explains the purpose of connecting them with capitalistic economy through commercilization. In today's community we dare to say retaining the feudal relation or staying inside of the selfsustaining shell can not promote the production, furthermore it is not afford to give any economic or social growth. Thus the very purpose of the agricultural co-operative association is. On process of democracy pervading upon the postwar villagers the system was conveniient to effectually modernize the farmers released of the feudalism. In other words we can say that the original function of the co-operative organization operated relating with new historical array of the village countries after the Land Reform.

Although too much was written in legal expoundation to think about the association. Regarding after the execution, the Agricultural co-operative Association Law first article has not spreaded with good comprehension in the countries. I would not like to say now, of cource that the agricultural co-operative association must be working right on the executive organization with the rigid legal articles. I am standing against such viewing but I descanted too much upon the character of the organization at the real tendency.

III

Considerable critics were made on movement of the agricultural association, however, nor individual person or occasion could be a source of the critics, neither some lack of genius of the association to be solved as a ideological problem. What is the motive ? It derives from fundamental conflict between the original character of the agricultural association of the co-operative system and the members of it being it's element furthermore with social quality of the farmers' community where it was settled.

I noted in advance that a co-operative organization holds greater force organized than a simple arithmetical sum ; A organization must do systematically gain members when it demands such a new power. To have members in an

organization, we take the every members to a standard circle of which comes out one big unit with balanced elements out of personal social rank, status or any talents. Any human or social differences are conjected to be an equal and principle unit for an association among which members such as premier landowners, small three-*tan*-farmers (1 *tan*=1/4 acre) of some others are. You would see the co-operative association's power is to make the members equal as well as the agricultural association has the nature of the same equalizing. But on the certain occasion we classify them for simple owner operators, landlord-operator, and bytenant-operator out of all farmers residing there while the farming scale also could be divided into only from three *tan* to fifty *tan* in many scales and the farming is also be sorted in professional, by-produce, or raising-vegitables, poultry, dairy farming etc. Each member of the association is farmer by name but in the real they are quite different notwithstanding the association has to have them balanced for membership.

To avoid this contradiction the agricultural co-operative association allowed the members being readily accessible to or from, and to set up for those on same type of farming an organization of uninvested co-operpative association. For example ; The operatership of dairy farming may be divided into different scale according to the number of cows, rate-consumption of forage, miliking quantity, technical ability which each one has. But secondly, possibility to do any or all of these is not exist in the communities which are not able to make synthetic federation because of the limited members. Such a small association like this shall not be capable to get information of technical training, financial operation, selling, procurement, scope of farming, scarcely can they do dealing of dairy products. Of course some part of the Japanese poor selfsustaining farmers could be organized but it is not the whole thing that must be completely regarded. Thereafter small scale co-operateve system was settled to solve the conflict of overhead agricultural co-operative association equalizing things orginally unequal by means of individual small scale association of the farmers who are raising partially same crops, even though the thorough eqaulizing is not finished and against uneqaulization and generalization of the farmers' originality.

At point of problem on the said conflict the works of the agricultural co-operative association in recent days, could not carried on certain methodes to increase production, except simply conventional and inveterate plain task. In addition, the first purpose of the constitution to make advancement on agricultural improvement of selfsustaining farmers after the law enforced seems to be neglected. Some associations having active directors seldom do efforts on setting engineer facilities or dairy work in villages. And on the certain occasion the facilities or the financial business do not bring effects upon the all members equally, but only some ones who can use these facilities conveniently would be granted the privilege.

The directors used to put stress on the genius of the co-operative association when they settled the facilities but often the members are not easily convinced neither using the privilege. That is reason why qualification of the work of the general agricultural co-operative association became inactive and uneventful.

Lack of investments, reduction of deposit, leaders' unskillfulness laid against the association movement as seen in advance for prospective expectation. There many associations finance the expenditure by routine income of management of agricultural bill, brokerage from quatus purchasing, fertilizers' delivery or selling in recent time. Upon the basic reason of the unavoidable conflict between the said equalization of the co-operative association and substantial unequality of the members who do not get along with th equalizing character. The problem of the conflict hereby remains on a standstill of difficult solution. If the association wants to correct the problem, it shall be engaged in many yeildings and business suitable to every members. You see : Some group wants to raise dairy milking, other is enthusiastic to grow vegitables and poor farmers might be pushed for money-borrowing. To prove of service to the sundry members it has to work on largely demanded money-lend, material purchase, crop-selling and farm technical guidance at least synthetically before then balance their wishing matters. When some one trying to do dairy farming only under lead of finance, selling, purchasing or information with cultural education of general works, his dairy farming can be cultivated completely well enough. Consequently any association special or popular in simple country, must be synthetic as well as the member-farmers cropping is synthetic.

I wrote before the members are miscellaneous taking many kinds of farm in the view of objective fact ; in the post-war condition it gradually departed from the synthetic qualification. Through the administrative reformation, the agricultural statistic and research works were transfered into the Statistic Office of the Agriculture Forestry Ministry, the guidance and extension works of agricultural techniques into the Agriculture Improvement Bureau. Of course aside of those offices in the administrative organization, some agricultural co-operative association or the federation could research and get information materials useful and availlable to the farmers whose livings to be raised up. Besides, the association itself having plenty enough of experts for the technical improvement or extension, can make fruitful progress on the agricultural betterment. Because of this reason, the administrative organization and the co-operative association do not alternatively swaying badly each other. But financial condition of the agricultural co-operative association does not yet submit to carry out research or technical guidance for the people. A certain agricultural co-operative association intending efficient agricultural improvement, ordinally have qualified experts but usually the technical guidance is not regarded so important because the leaders at

the Agriculture Improvement Institute do the same.

Generally the extension stuff of agricultural improvement office came from different birth of the experts at the agricultural co-operative association. We see that the first one has charged it's own field individually leading the farmers and bringing them up with their agricultural improving scheme. Otherwise, the latter one of the experts of the association has contact with the farmers not only upon the special techniques but also giving guidance or hints for their living and all the productive affairs in the limited areas like as the synthetic works that the co-operative association exactly showed us.

Thus distinguished in the origin the works of research and technical extension became unactive in the co-operative association beyond the finance lack of the association becoming lost its proper synthetic quality for the government established a similar organization through the country and even in the rural districts. This is of public knowledge.

With the research and the technical guidance, many other works naturally belonging to the association, have lost the places there. For instance: Prefectural Training School or such Hospital engaged with certain association. Paymasters' School was estblished as training school for accountants of an unit co-operative association before operated by the federation of co-operative association in every prefecture. To bring up the staff members, the federation treats the pupils in excellent methode so that the training effect gives way to democracy. Nevertheless the critical finance condition pressed the works into the hands of the Prefectural Government, losing the synthetic quality of the association. It is apparent that difficulty to cover the outlet for the officers, and the poor managing policy of the association caused the nature of the loss. The mental support that the agricultural co-operative association entirely depends on, is intentionally demanded by the association, accordingly the school under the association's administration is the duly sufficient to train the pupils in getting the genius. The one who passed the worthy school as earning pole of the spirit into the hands of the government is just as if he would have sold himself.

The loss of the synthetic character of the agricultural co-operative association is not only found in the said point of guidance, but also in finance and purchasing or selling business enterprises. I am not able to mention the real figures but it is evidently notable that the deposit of association decreased and the prosperous usurers developed into villages for the last few years. The government contribution system of staple food still runs the selling business for the trademen's growing. Especially the increased fertilizer-trademen will make a greater loss on the purchasing business for the near future with the problem loomed larger than ever. Of course the work have turned not quite wrong and trying recover it again though considerable partial loss takes serious tendency to the synthetic quality.

Consider the large part of the remark; The agricultural co-operative association as one of the co-operative organization has power of the equalization upon the individual members in the social and human attributes in spite of the fact that each member has strong unequalization among conflicts. And to correct the contradiction, its function is complicated so that the association have the synthetic force. But the force became partially reducted under the reformed administration made by outsider, furthermore the slightness of the organization's function makes the operating fields occupied by the bankers, usurers and trademen, being shorten with the weaken synthesis. Than that the agricultural co-operative association normally defending the poor farmers against the usurer's capitals in the days just prior the Japanese modern age to stop their fall, it is going to lose the time-honored operation.

What made the contradiction that is standing up before the association's movement ? The basic reason is found out in the spot of that the very antithesis between modernism of the agricultural co-operative association and whose dependent community's untimodernism. The equalizing function in the co-operative system means to treat all the members averaged from their proper attributes for example ; farming scale, classification by land and or shared capitals sum. That is as one way of democracy. You would have seen the democratic equality at every section of corporation, though the agricultural community is not modernized to be thus reacted. We sometimes hear considerable number of directors elected under most democratic and modern like rule and manner are sometimes feudalistic farmers in ideology in accordance to large members of a modern-democratic-seemed association that is still holding feudalism.

It is reliable if large number of the members would be untimodern, that the officers elected by them, shall be the same. The reuglation or its realization would be modernlike with the equalization of the characteristic association so that the business enterprises could not fetch any excellent and efficient results. Provided that the untimodern staples grow platitude as I before pointed out, the works become vulgar with demanded systhesis hereafter. Frequent sluggish, finance-scandal failing, directors' persuasion or independency loss against government control nonschem-scheduled business enterprises and ignorance to agricultural improvements, all of these were arisen around the basic conflict between modernity of the association and untimodernity of its members.

In the view of history, the Japanese agricultural co-operative associtaion was formed by the small scale owner farmers arised of the Land Reform as a partworker for the modernization. However, I can not neglect the fact that the poor farmers of the reformation are still small-scale raising and selfsustaining in the longkept untimodernity under the commercial economic influence. The problem of the deep conflict derives from this profound valley where the agricultural

co-operative association of the modern corporation system has worked thoroughly upon the peasants. Trying to find out the way of the solution of this problem, we have to face criticism about the agricultural corporation.

IV

To actually accomplish the aims, the agricultural co-operative association shall grasp the meaning of subjects with analysis and criticism. The directors of the association and the auditors and also the member farmers shall not carry on its first object unjust and unright under stress of some proper opinion with a too simple co-operative devoting thought. Otherwise strictly being pushed for certain intention of some outsider such as from an organic agency or potential government which is far from helping its sound growth. Very often we see some unactive association having no its own intention makes decession by outside authority for village which is the place for the establishment in depth of the feudalism. Then the fundamental first object of the association must have taking off the feudalism for growing the modernity there. The organization is ordinally made up democratic and independent at its constitution even though the inner part of feudalistic character stands firm far from the edge of democratic world. Answering the question how they could make it right, they go up to high bank beyond of the untimodern farming, for and of which the corporation has its existing reason on the farm modernization. If they could not find any thoroughfare to the independence without support of outer association, they might have no destination to carry on the purpose. Then there shall be not any high-handed proceeding push of the outside as a government while directors shall have the workers' training for the farming improvements, and for getting ability to restore the liberty. If the expected highly trained worker under control of the organic corporation, takes place at the local unit corporation, the business perhaps shall be more vigorous than before. I hope that this training is not simply giving them mere finance proceeding techniques but also making them more powerful and progressive with fully systematic scheme.

In the proof of the membership in social status, the organization finds itself weak at the real situation that is not readily correctable, however I here accent that the association has the rule to promote the improvement by the energish hands of the workers never being allowed to stay asleep or having the organization with vices. We see some active association always has excellent manager or workers. The lack of the organic corporation to give them high instruction, energy or training opportunities is now the problem to be pointed up. That is why the business enterprises became blighted in the activities. In every section of taxation, correspondence, labour, welfare, agricultural statistics etc., the workers efficiently

take places after sufficient training, but in the agricultural co-operative association the workers start on duty in short term training of the mere fundamental financing. Thereupon the most important movement of the agricultural co-operative association might go slowly, I think. The very prerequisite is to bring up the workers to become men of intelligence and endeavour.

The second problem of the association's weakness depends upon the fact that the co-operative association with the members going to be equalized in the working field, but really it is not easy to be realized. Rather oppositely, the function is platitude along the simply normal way of the business enterprises because of the multifarious members. Consequently, the synthetic character of the function of the association was not demanded for the members' production and neccesary commodities but it was the formal synthesization abstracted by the so many kind of farmers by occupaiton. There is apparent differency between those two transaction of synthesization. In the platitude synthesization the association has so many enterprises that would not breed good fruitage for vain. Other synthesis supported by productive and living demand, has come from the agriculture itself operated after the farm revolution as the poor small scale farming ; for doing something of a certain intention. In concluding, the agricultural corporation shall be better not to insist the just platitued sysnthesization whereas it shall have an intention with the synthetic quality upon the operation by the staple body for the farm revolution.

I preparatorily noted that the association has perplexity on its own birth as it was formed by almost all of the postwar farmers by means of the transmutation of the war-end complication. Otherwise in Japan the farming villages want to be modernizaed ; to be economically modernized as a part of the national market. In this situation, the villages shall go in somedays to have the good role to produce commercial goods out of the simple commercialism that brings no high profits. The business enterprises shall be transacted only under the farm improvement but until today the large members have the opinion on the tongue not on the hands far from the problem among the association trends, and this is reasonable along my explanation in the former chapter.

Finally one more fact is to be mentioned that the directors of the organization do not know the actual figures about their own community. Usually no directors of such corporation are there who do not know the community's tendency. I mean if some one dwelling there and regards after the surroundings with personal relation, that is not plenty enough to say him knowing the circumstances. I think the organization has been kept the members' quata books and files of bills stated in-or-outturn of fertilizer, farm-machines or similar equipments. Moreover there are books of deposit and loan noted ot detailed income, outlet and lending by person. That would be one of most reliable material to make every thing precise

and concrete in consolidation. Why the directors or others seem unknown more and better than the books have included ; because of that the matericals are not filled in order for decided purpose. The biggest survery by the Agricultural Forestry Ministry was worked through the whole country with 6,000 farm households in finance matters. The number may be the minimum one with which the Government is capable to contact. But if the local agencies would set an intention to do the same, thereafter, those perhaps could make it out consolidated with the so vast deal of the materials. While the survey methode was taken by the Agriculture Forestry Ministry more systematically and other research before conducted by the local farm agency is gradually becoming lost the synthetic quality. But if it would set an intention to make an improving reformation upon the agriculture, the work is not so hard to be achieved. During it remains with the platitude quality, it might have no need of such research-work, of course it also shalll not be capable to strive for even a bit of lost synthesis.

An advancing association first shall take the work of survey, which efficiency shall give an administrative instruction to make the association's function well-qualified. Generally, in an old village several proper quarters are divided along with the agrarian or traditional condition. In those quarters each social classification or farming individuality is different. Among those farmers, some one's living is stabilized with rich net-income of the farm products, others are almost-stabilized and have sometimes small deficit. All those are called stabilized farmers. In TOHOKU region, 20% belongs to the circle having over rate-two-*cho* scale. Why those could be stabilized in the village ? The reason is depending on the condition of both farming scales and managing methodes that provides some suggetion to the prospective reformation. When some farms by addition of fruit growing, or dairy farming, or poultry farming could have the profits increased, in another village farmers under similar conditions could advance in the said dairy or fruit raising. How much percent of unstabilized farmers out of those stabilized, or else how much grade of farming-scales could become stabilized ? That comes out of technical methode and investments of the capital or selling business enterprises. We found the problem shall be dissolved by the all hands of the agricultural co-operative association.

The suggetion gained by the survey, could joint small scale farmers for specific products for example : poultry or dairy farming in a fractional co-operation association. In an extremely view, very small combination would be settled by each group and the similar combinations go multipling in an almost unlimited number. But mostly, every village is not used to devide into so many groups but fractional combinations can make a great general, agricultural co-operative association to let them standing independent as small ones. Any way, those small associations form the main body of the agricultural improvement, where the real

situation of the agricultural co-operative association is reflected.

Since the agricultural co-operative association has been established, the active body was an unit corporation charged by the general agricultural association in each village, and the government remedial measure also transacted by the hands of the association. Within the government control it was reasonablly available for the government. However the general agricultural co-operative association easily has the platitude synthesis from complicate of its inner function. To do better correcting for this, the small scale productive corporation were established one by one for each kind of the function.

Let me now think of the fact that by the new born many small and characteristic associations the general agricultural co-operative association shall lose the reason to exist ? It is readily seen that after the many productive corporations were formed, the work of the general agricultural co-operative association shall dismounts inversely proportional to the raising growth of member famers. Neverthless, there are some business enterprises, which are not entirely suitable to the fractional combination but equivalent to the general organization : for example ; the financial operation, that is not to be carried out by hands of the small unit in spite of the specific needs, and it is unsuitable and uncomvenient to be transacted in the small circle. The unit corporation does not permit a group as a member. I like prefer that it would be better to take a change of accepting any small group for membership provided that the one grown inwards in development of the general agricultural co-operative association in the future.

The cultural information and research workes also belong to the general co-operative organization. In the recent time, the associations do only publication of newspaper or hold short time training as the cultural work and no researchings are conducted there that I priscribed before. The technical guidance is also belonging to the general co-operative assocaition. Each of the small productive associations wants to gain proper techniques as well as the members' routine works with the special one for instance poultry, livestock ; would be better to recieve guidance to make the farm and life adapt for the village-trends. Though the government extension works on the improvement, I think, the technical experts are earnestly required for more and more advancement.

After the small productive associations have advanced, works of financial operation and guidance could form a general co-operative association. And that seems capable to operate the ordinal roles of the organization and its holding, but not completely now. It would be better to take a role of incorporated business of staple food and neccesary commodities. Up to date the procurement agency was established to boycott the commercail investiments of vicious merchant and the brokerage ; to defend the poor farmers falling down into the depth of usury burden of the scanty economy. The staple food and chemical fertilizer shall be under in-

corporated business enterprises but when the economic fluctuation waves in large scale, the joint purchasing of numberless commercial goods shall be corrected. This must be of worked by motive of the synthetic quality of the general co-operative system, but it is simple opinion platitude. Regarding after the transaction for the high and firm purpose, the incorporated business enterprises shall take place in order and by good turn under complete control, to hand cheeper goods to the farmers. Only in the case that is most desired if the joint purchase makes profits for the farmers. With long time shop-worn stock high priced than the things of the general merchants in the community, the operation makes the capital currency brisk for none of nonsence.

In conclusion, the incorporated association as one of the co-operative system has an intention to equalize all members in the democratic way. It includes the conflicting equalization involved with the poor and selfsustaining Japanese peasants in the marketable economy of what the unevitable synthesization happens. We now see in present time the agricultural co-operative association with platitude syhthesization make the great general agricultural co-operative system, however it is not much helping the agricultural modernization with the agricultural co-operative association. The systematic and cubic quality of the co-operative association is more worthy than that mere platitude and serial. The existing agricultural co-operative association first forming up the main body of the agricultural improvement by the right survey at its own country besides releasing the productive or small association free and active, in solving the troubles and in endeavouring the purpose of the general agricultural co-operative assocaition to be accomplished at all. Then the platitude and multitaneous works of the general agricultural co-operative association shall also be in order to realize the very purpose of the agricultural improvement, I think. Especially the works of technique and guidance and financial operation of the general agricultural co-operative association, shall take the frontplaces, meantime the purchase and selling business shall be at right point of the research-work.

If we can success to transport the poor farmers after the inaugulation of the Land Reform Law into the right marketing line, it shall be well adapted for right available to making the agricultural production increased and the farmers' economic-social status arisen for the national economic advancement forwarding as it is claimed in the first article of the Agricultural Co-operative Association Law. To make this realize, we must have some change on the law and along its enforcement, and before that the members themselves have to grasp what the theory of the co-operative association expounds.

Summary

Since the inauguration of the Agricultural Co-operative Association Law in March, 1943, innumerable associations were established in Japan but most of these except few associations, are becoming weak in administration and operation. I worked on the cause and it's solution. In the outcome, the brief is as follow:

1. The power of the incorporated organization is a power of number in a mass. It has essential nature as it is seen in every space of country and period so that it is called superhistoric power. However it must not be conprehend without illustrating of historical human society when it is for a productive power of the utility of mankind.

2. As one of the co-operative system, the agricultural co-operative association also has the historical and social individuality. It was formed by the small scale-owner farmers arisen through the Land Reform that started the first step in 1946 for the revokation of the production related with the proprietiors within the feudalism, forwarding to location progressed in the economy and society. It is to be pointed out that the purpose layed out of common attention.

3. Very ordinally, the real member farmers have strongly characteristic unequalization where as it works on equalization of their social and human attributes. To correct the part of its contradiction, thereupon, it has to carry on researching and furnishing of the cultural information, technical extension and improvement of their daily life and also business of financial operation, selling, purchasing and manufacturing facilities in synthetic operation. While it becomes weak because of the too multifarious works, it's function remains platitude with the directors who were elected among the untimodern farmer's circle.

4. If the agricultural co-operative association would recongize the specific nature and set an intention to promote the farming modernization in accordance of its fundamental purpose, it has first to take a survey about the real situation of their farm holding. Such incorporated organization shall be formed by the farmers who lives under the similar condition what is abstracted of those who grew the successful production. But the business of investments, delivery of farm equipments, technical extension, cultural information materials wants to be operated by the joint hands of each general corporative association in each village. The Japanese farmers are afford to make themselves modernized in cublic and systematic organization associated for the commercial farm production.

On the Social Economic Character of Farm Management*

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I. Foreword

The improvement of farm management means, to put it in the concrete, its change for better. Now in order to change the method of management, it is most important for us to realize what management is and how we should understand it. At present how do most people take it ? So many men, so many minds. Then why such a kind of chaos prevails ? Many reasons may be thought of about it. First, if there are ten thousand farmers, so many different conditions exist ; therefore it would be difficult to draw a line common to all them ; even if it were possible, to what could we apply this line ?

Second, the fact that there is technique as well as economy in management is another factor to bring out the chaos. And each of them has its distinct rationality. Consequently how we should treat these two comes to be a question. So we shall begin with the problem of how to consider or treat this management and then proceed to the explanation of the charcter of farm management in our country and the examination of rationality in it.

Production is indispensable in all ages and in every society, its method, varies with the particular age or society. Rice is, for instance, grown in other countries than Japan, and was in the Tokugawa period in Japan. The way of growing it is, however, different between Japan and China, or America, and in Japan as well, it differed between present day and the Tokugawa period. This needs no explanation. What is important is how we are taking it. The fact that

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the method of growing rice varies with a country or are is due to the different rationalities current in the particular age or society. This most important.

In other words, owing to the social economic character of mangement as a unit of economy or production, different ways of production or technique are necessarily caused, and not vice versa. This means that we should understand rightly what management is, and that to grasp this meaning we should recognize the social econimic character of management. It cannot be denied that technique influences this character, but technique cannot exist without certain difinite social conditions.

Therefore, it is necessary for us to difine the historical and social economic character in order that we may draw a line common to the management with apparently various aspects. Technical rationality does not necessarily correspond with that of economy or management. Conversely, tehcnical rationality should rather adapt itself to economic one throughout the management. Thus it becomes imperative we should know what economic character the farm management has, and what kind of rationality is current in it.

II. Economic Characteristic of Management

Opinions are divided in how to difine the conomic character of the farm management in our country.

There will be no question in that our farm is not completely suited to any capitalistic enterprise and that it has feudalistic character. This is an important point, but for the time being suffice it to say that ours is typically the management of single commodity economy in the sense that the production of commodities are carried on by family labor power. Therefore, the labor production theory or production cost lowering theory in the past, making no distinction between family labor power and employed one it, we should say, only a mechnical view which does not distinguish capitalistic farms from noncapitalistic ones. It is only natural that the more or less primitive farm management in our country and the advanced capitalistic one in Europe and America differ in the way of realization of economic rationality.

Needless to say, the object of management in the capitalistic agriculture is the pursuit of profit. The rationality in this system must make for the direction of getting profit as much as possible. Lowering of production cost and high development of labor productivity, that is, rationality, cannot help but depend upon how to raise the labor productivity. Herein arise the concrete problems of economy or exclusion of employed labor power and strengthening of labor for the sake of profit.

Whereas the farm management in our country based on single commodity

economy cannot aim to get profit like the above-mentioned capitalistic management, because the labor power in the farmer is not employed one bought as commodity, though we don't deny that there is wage labor to some extent even in our country.

The ratio differs with farmers, but generally speaking, family labor power farms 97 or 98% of the total farm labor power in our country. This does not mean that the function of employed labor power is worthless, but it is evident the farm management in our country is based on family labor power, which is also the reason why it is called family farm. Then what is the object of management and what does it mean?

The first thing to be considered is wages. (laborers', character). Next we may think of surplus as a kind of enterprise, and land-rent when farmers happen to be land-owners (capitalistic or land-lords' character). But it is a quesiton if the surplus or land-rent can exists generally. At any rate what farmers seek to get actually is wages, and not profit. (A part-time farmer gets wages and other kinds of income besides agricultural one).

In other words, what farmers seek is to get is surplus operating expenses deducted from agricultural income — it is in reality nothing but wages. This agrees with the fact that no production price is realized in the present price structure of agricultural products. Of course, farmers are not pure laborers using only their own hands and feet, but a kind of enterprisers with means of production such as farming tools and cattle. Therefore, what is important is how to get more agricultural income, using rationally their own available means of production, on the basis of family labor power (whether farmers get surplus income or not depends on household expenditure as well as on the increase of income). Insomuch as what brings forth value reamins to be family labor power, this power must be made most of to production. Therefore, in such a management, using up of labor power is the first essential condition. Thus, in order to get products as much as possible with limited family labor power, it becomes necessary for them to work hard with little rest, compelling children as well as old people to work. So that so far as productivity is concerned, what is important is the capacity of all the family, and not that of certain individuals. The fact that most devoted farmers are almost superhuman and that farms with few laborers are poor is the effect of the same cause.

Such being the case, diversified management comes to the front, especially in depression days, because such management makes farmers get a stable source of income as well as diversification of risks, moreover, it will enable them to use up their labor power into production. And in order that they may get much production out of a fixed managing area, with a certain limitation of family labor power, additional yield or land productivity comes to be considered. If managing area is small, the labor power must be used more intensively, thus causes waste.

So long as the farm management in our country has such a character, exclusion of means of labor is inevitable, for economy of family labor power by using machines does not necessarily lead to increased yield or the increase in balance of agriculture. Herein lies a limitation of productivity. Moreover, if thus economised labor power cannot be directed to other employments, these farmers simply remain to be consumers, lessening no household expenses. Accordingly farmers cannot help being negative to mechanization. In short, how to rationalize family labor power is the key point of management. In keeping with this line, we should make most of means of production effectually. Then from the above characters, what characteristic can been seen in the economic character of management? As this characteristic, we may consider middle-class farmers (full-time ones).

1. Self-sufficing production and commodity production.

Agricultural production may be divided into two kinds — self-sufficing production produced and consumed within its management, made up of food for family use and self-sufficing feed and fertilizer, and commondity production for market. Many products cannot be made any distinction between the two at the sight of them, not because farmers produce them at their free will, but because conclusively their productivity is low and their labor power is not a mechandise, but family labor power. It is only when labor power becomes wage labor that all the agricultural products can be brought to market, and such a kind of agriculture means to be capitalistic. Therefore, Japanese farm management is obliged to have dual characters of self-sufficing and self-supporting natural economy and market economy, and it is impossible to separate these two. Rather production for market is effected based on self-sufficing production of natural economy. In fact it is not too much to say that there is no farm in Japan which does not depend on food for famliy use, self-sufficing fertilizer and feed, on the other hand, all the products cannot go to market. Therefore, we must not forget that the increase in balance of agriculture does not necessary mean the increase of cash income, especially when products are not divided into commodity products, and those for family use. At least it is necessary for farmers to secure the minimum self-sufficiency (for example, of food) neither stability nor lastingness can be conceivable at the expense of self-sufficiency. Of course the development of commondity production heightens productivity, thus relatively lessens the rate of self-sufficiency, but self-sufficing production cannot cease to exist under the presset social and economic conditions. In fact fruit-farmers of mandarins, apples, et al. don't stop rice-growing, because they want to secure food for family use. The problems of Japanese farms lie in this very point. This fact does not mean the necessity to strengthen self-sufficiency, but the necessity to

secure the minimum one, at the same time the need to increase commondity production. This may sound irrational, but is rational in the management under the existing actual conditions. Therefore there is a certain limitation in concentrating on products economically advantageous, hence a kind of condition in productivity. When products are not divided into commodity one and self-sufficing ones, they take the form to consume them and after sell the rest (but actually they sell and consume the rest), so that the increase yield, namely land productivity comes to be at issue.

What we should consider here is that the calculation of cost is difficult because of the portion for family use, or impossible in a sense. Even if such a calculation were possible, as we shall mention later, production price would not be realized, because they do not manage production with the object of getting profit, thus it is difficult to make management clear by bookkeeping, which prevents the management from being carried on rationally.

Further, in order to make products marketable, we should take two courses into consideration. One is that of full-time farmers who sell teir produdts and the other is that of part-time farmers who sell their labor power as it is, because they cannot use their power with in their own management. It is needless to say that stability in management exists in the farmer, thus develops a natural course of intensive crops and intensiveness of labor power for the sake of specialization.

2. Agreement of production with consumption.

In capitalistic agriculture, household expenditure and other personal consumption exercise no immediate influence on production, so long as they are consumed within the profit, as they should be. Whereas in the farm management in our country which is operated by family labor power, production and consumption, management and household economy cannot be separated. That is to say, consumption must be at once productive consumption, because farmer's income is effectually wages and family consumers are producers as laborers. Such being the case, it become imperative to use petty labor power of children and old people. So that rationalization of household expenditure is at the same time that of management, and vice versa. In order to get farmers' surplus profit, therefore, economy of household expenditure becomes necessary not mention of the increase of income. The fact that no production price is realized in the products under such a management makes it inevitable to cut down household expenditure. Moreover, if they want to get any surplus in management with the intention of enlarging it, the economy of household expenses is indispensable. This is the reason why the principle of thrift and diligence is inseparably connected with farmers. Hence an indiscrimination between family life and job, and a combination dwelling and workshop of a farm house.

3 Separation of production and circulation.

In the capitalistic management, all the products are sold, while various means of production like farming tools, fertilizer et al. and employed labor power are purchased. All the products come to be circulated. In our country, however, parts of products are sold and the rest consumed within the management. Therefore production does not agree with circulation. Such a management is naturally in a small scale, because its size is restricted by family labor power. Moreover since only a small portion of products are sold due to family labor power, those which are to be circulated are necessarily small in quantity. In other words, farmers have little capacity to sell their products. Consequently, if they want to carry on reproduction smoothly, by connecting production with circulation, they must resort to other capital than their own, namely to pre-capitalistic commercial capital, not modern trading capital, which tells, in its turn, why production price made up of cost and average profit is not realized with such agricultural products. There can be no trading capital where profit cannot be expected, and commercial capital serves, as usurer capital. We shall be able to see these circumstances if we think of fertilizer merchants and rice dealers in the past, or the present fruit factor. As is well known, co-operative societies have been formed with the object of protecting those farmers from such merchants or usurer. This condition remains unchanged even now.

We have said that farmers are ignorant of the production price of their own agricultural products, but this is not without reason, since those products depend on market prices. Therefore, it will be natural to some extent that a panic in agriculture appears to be beyond human power for farmers like natural calamities of flood and cold-weather damages. Thus if a price depends on other factors than their management, if will be necessary for them to increase yield, for the purpose of increasing cash income. Anyhow with the progress of the tendency that agricultural products are produced in a commercial scale. we should attach more importance than ever to the systematic circulating process of sale and purchase. This is a condition to protect and develop management.

III. Limitting Conditons in Agricultural Management

To improve farm management, agricultural productivity, productive capacity of all the family must be heightened, as we have stated above. The next problem is to recognize what conditions control practically the development of such capacity. They must be fundamental conditions which have brought forth economic characteristic in the present management, and not particular and individual problems such as the number of family members, et al. The reason why we should

now inquire into controlling conditions in such a management is that the one in our country has not yet become independent enterprise as we have already described and that it depends upon external conditions rather than internal ones.

From such a point of view, we may think of two conditions controlling management. One is the system of land property and the other is capitalism. In the sense that the management in our country has not yet reached capitalistic one and is influenced immediately by land, we shall first discuss the system of land property.

1. System of land property.

The problem of land has further meaning than that it is essential of agricultural production. It is not enough to say that land monopoly prevents the development of the management. Nowadays it is impossible for farmers to live in villages without possessing any arable land, which necessarily means that they are under the immediate rule of land-owners. Actual examples are tenant-farmer, petty or part-time farmers, thus there is no room for capitalistic tenancy (management in a large scale) to exist. Consequently loans of land are not to be mere lease. As a rule, only tillers can live in villages and tenant-farmers cannot get land enough to use up their labor power. Thus their superfluous labor power turns into employed one of land-lord framing and rich farms. Here we can see a meeting point of land ownership and labor power control. In other words, this does not mean mere land monopoly. Under such circumstances, the enlargement of management and development of commodity products are extremely difficult.

The fact that marketable crops such as mandarins, apples, et al. in our country are grown among hills and inclined places, not on levels in caused by that they selected those spots where the pressure of landlord land ownership was slightly felt. The reformation in the system of agricultural land has turned many tenant-farmers into land-owner and breed them from the burden of rent in products into commodity producers. Rent has come to be paid in money, instead of being paid in kind. This is really a development. But conditions of petty farmers and part-time ones remain unchanged as they were, and tenant farmers still exist. The rule by land ownership still remains and forms the basic controlling condition against the development of management. Since land is most inportant to agriculture, no development in management cannot be expected unless this condition is removed. Besides, land-owners are at the same time owners of woodlands and fields, many of them being merchants or usurer capitalists.

2. Capitalism.

Capitalism and farm management are closely related with the system of land property. The fact that we must take capitalism into account, outside farm

management means that the latter is not yet capitalized and by which we shall see it is under the rule of land ownership.

Since farmers are obliged to sell their agricultural products or labor, they naturally come in contact with capitalists. In other words, in the matters of sale, purchase, funds et al., they are forced to keep in contact with various kinds of capital, from the pre-capitalistic capitals of merchant, trading, financial and usurer ones to monopoly capital.

There is a problem in the point that thus they are at the mercy of two kinds of capital, modern capital and earlier pre-capitalistic one.

Concretely speaking, they face with the peroblems of sheré, various burdens of taxes and public imposts, wholesale merchants, usurers, et al.

But so long as they want to heighten agricultural productivity or develop commodity production, they cannot get out of touch with capital. Therefore how to prevent its exploitation is a vital problem to bear in mind. At least it is desirable for them to do their utmost to prevent the touch with pre-capitalistic fund through other means such as cooperative societies. In short it is owing to the exploitation of capital that farm management comes to be in the red, finds it diffecult to reproduce that farmers are obliged to cut down their household expenditure and that the condition of the development of productivity disappears, with no surplus income. The flowing of unemployed population back into villages is another result of the pressure of capital. Now farmers are not only subject to such exploitation, but theire is some foundation in villages which makes it necessary, this is a point we must turn our attention to. It is a problem of capitalism and agriculture, but the fact that the farm management of present days is carried on only by family labor power is, of course, a result of capitalistic rule, which rules agriculture directly through the system of land ownership.

To judge by common sense, Japanese agriculture is subject to dual rule, the direct one by the land ownership system favorable to land-lords and the indirect one by capitalism. No epoch-making development in farm management is to be expected without the exclusion or relief of this dual rule. Therefore though we may say that the controlling conditions of management are external ones, we must not forget that they prescribe internal conditions in the management and have intimate relation with them. These controlling conditions are beyond the ability of individual farmers, which are, in this sense, a sort of political problem. We can find a particular character of our country in the point that management is directly connected with plotics.

IV. Postscript

So far we have stated that the farm management in our country has

common character. As long as it is based on family labor power, this character will apply to every sort of management. But the farm management cannot be of equal quality in respect of its social and economic character, which is quite evident since farmers' are class society. This means that economic laws current in the farm management varies with farms. For example, full-time farmers and part-time ones are plainly of different character, though they are classified as farmers. As the way of their contact with land or capital differes each other, so their way of being ruled by them varies.

The how should we classify the famers in our country ? We shall divide them into the following four classes, according to their land ownership and labor power.

1. Poor farm management.

This class consists of tenant-farmers, petty and part-time farmers (wage laborers). They belong to the stratum of farmers who cannot use up their poor family labor power of small families, in tilling their own land. The present agricultural policy has nothing to do with this stratum. There is little room for the improvement of management and no remedy for them but political solution.

2. Middle farm management.

This class consists of full-time farmers, and most of them are land-owner. They carry on their management by means of family labor power, and are most earnest in their effort to better management. Some of them are destined to fall to poor farmers, and some tend to go up to rich farmers. The rationality of management thus far described applies best to this class. The agricultural policy in our country is chiefly directed to this stratum.

3. Rich farm management.

Farmers in this class are land-owner and full-time farmers and can afford to use employed labor power, a part of them are land-lords and yeomen. They have conditions with which to enlarge management and develop into capitalistic agriculture, in this point, the rationality of capitalistic agriculture comes to be a problem. It is a question, however, they have actually such conditions. Actual state of things in our country showing the tendency to turn into middle farmers will tell us that they are taking a negative and backward course. In this sense, the trend of farmers in fruit-growing districts calls our attention. Anyhow, unless the condition based on family labor power collapses, any development into capitalistic management will remain to be difficult.

4. Land-lords farm.

The reformation of agricultural land has reduced this stratum, but land-

lords yeomen have not much decreased in number. To those why belong to this class, the improvement of farm management and development in agriculture are almost out of the question. What they are concerned about is that owing to the development of poor and middle farm strata they are hindered in their activity as land-owners and usurers, with some rich farmers.

In short, the improvement in farm management is chiefly concern to middle and rich farmers, not of poor farmers and land-lords. And the development of the famliy management in our country means the raise of productivity, the increased commodity products and the approach to capitalistic agriculture. The rationality in such cases is as we have stated above.

In addition, as a problem of management, we must say a word to technique. But technique is to be discussed only under the social and economic character of the above-mentioned management. Regardless of such a character, any discussion of rotation, land fertility, fertilizer or farming tools will have nothing to do with the problem how to change the farm management actually.

Summary

The object of the farm management in our country is not to pursue profit but get income. This actually means family wages, because labor power is family labor power, and not the one bought as merchandise. Therefore the economic character of management has the following characteristics.

(i) Self-sufficing production and commodity production.

Agricultural production has dual character of self-sufficing production for family use and commodity production for market. It is impossible to lack either.

(ii) Agreement of production with consumption.

Consumption for family use is the premise of production and it is impossible to separate management from family economy.

(iii) Separation of production and circulation.

All the products are not marketable and the interference of precapitalistic merchant capital is inevitable.

The conditions which actually control the development in management are the system of land property and capitalism. Without the rational solution of these two conditions, any development of management is not to be expected. Further, to develop management, we must purpose the rationality adapted to the economic character of management. In other words, it is necessary to change the methods of improvement in management, according to the different strata of land-lord, rich, middle and poor farm managements.

Tank Breeding of the Japanese Surf Clam, *Mactra Sachalinensis* Schrenk*

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and Seiichi SAKAI

(Received January 10, 1953)

I. Introduction

The Japanese surf clam, *Mactra sachalinensis* Schrenk, is distributed widely along the coast of Hokkaido and Tohoku District in the northern part of Japan and furnishes an important clam fisheries locally. The optimum habitat is sandy shallows to a depth of 4 meters along the open sea. Natural spawning occurs in spring when the water temperature rises to 14–15°C as Kinoshita[3] (1934) reports in his Hokkaido studies. In Miyagi Prefecture spawning occurs in the later part of April on the beaches of Sendai Bay and in the middle or later part of May in the sea north of Kinkasan.

Because of its economic importance, this *Mactra* has been studied to some extent, mainly by scientists of the Hokkaido Fishery Experiment Station. Kinoshita and Hirano[3] (1934) studied the temperature range for the normal development of larvae. Kinoshita and Ishiguri[4] (1940) and Kinoshita[5] (1948) reported on the growth of the shell and also on the life span of the clam. Based on observations of marked specimens, Kinoshita eastimated the life span to be over 20 years. Kinoshita[6] (1951) analysed the fluctuations of clam fisheries in the Hokkaido area. So far its development has been followed to the D-shaped veliger. The biological knowledge to date was summarized by Cahn[1] (1951).

The writers succeeded in rearing in tanks the larvae of *M. sachalinensis* which had been obtained by artificial fertilization, and in collecting large number of young. Thus they could follow the life history of the larvae up to metamorphosis

* The 87th report of the Institute for Agricultural Research, Tohoku University (1952) and Contribution from Onagawa Fisheries Laboratory.

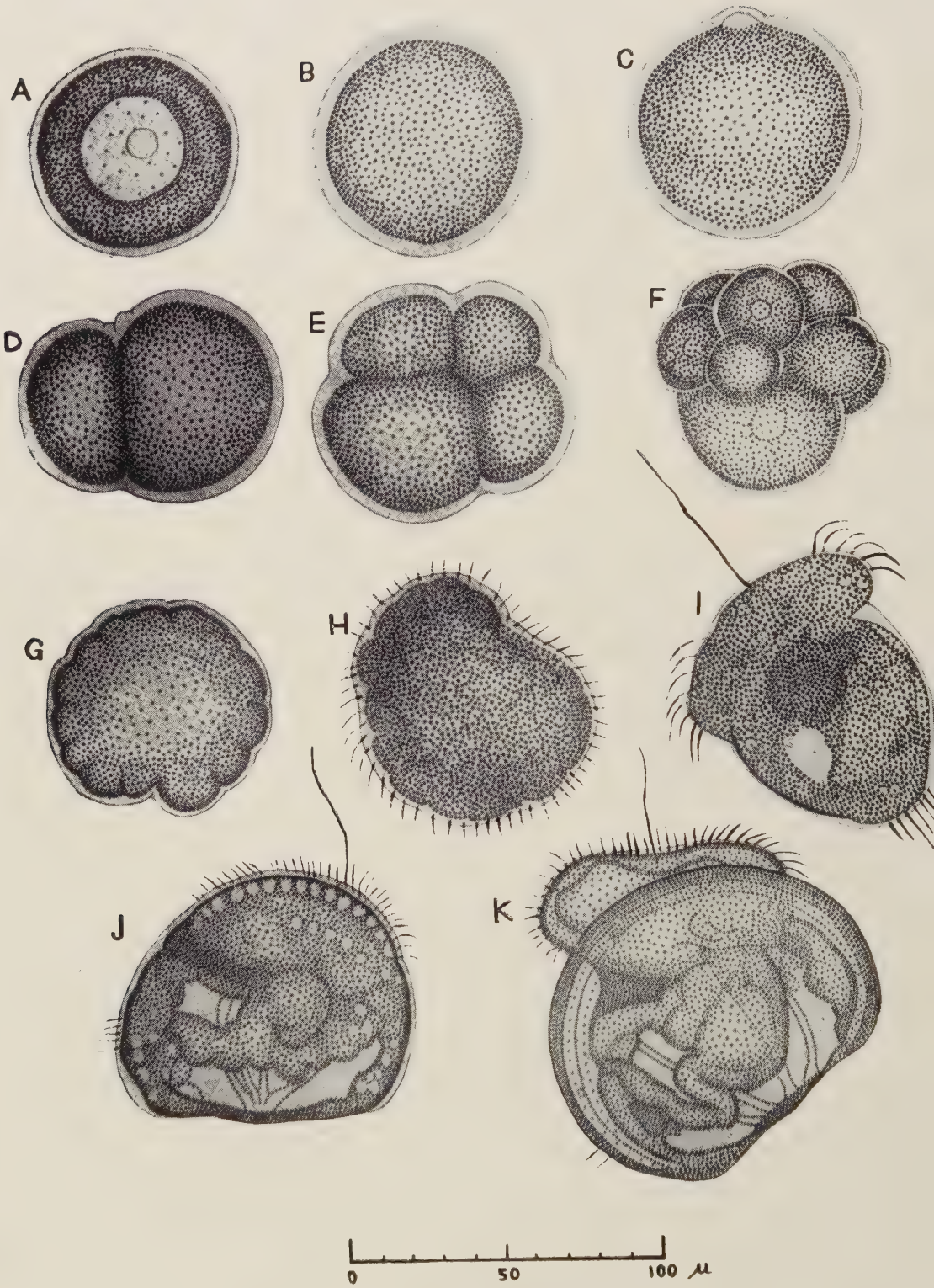

Fig. 1. Development of *Mactra sachalinensis*. 2.

A. Matured egg. B. Fertilized egg. C. Formation of first polar body. D. Two cell stage. E. Four cell stage. F. Eight cell stage. G. Morula stage. H. Blastula stage. I. Trochophore stage. J. & K. D-shaped veliger.

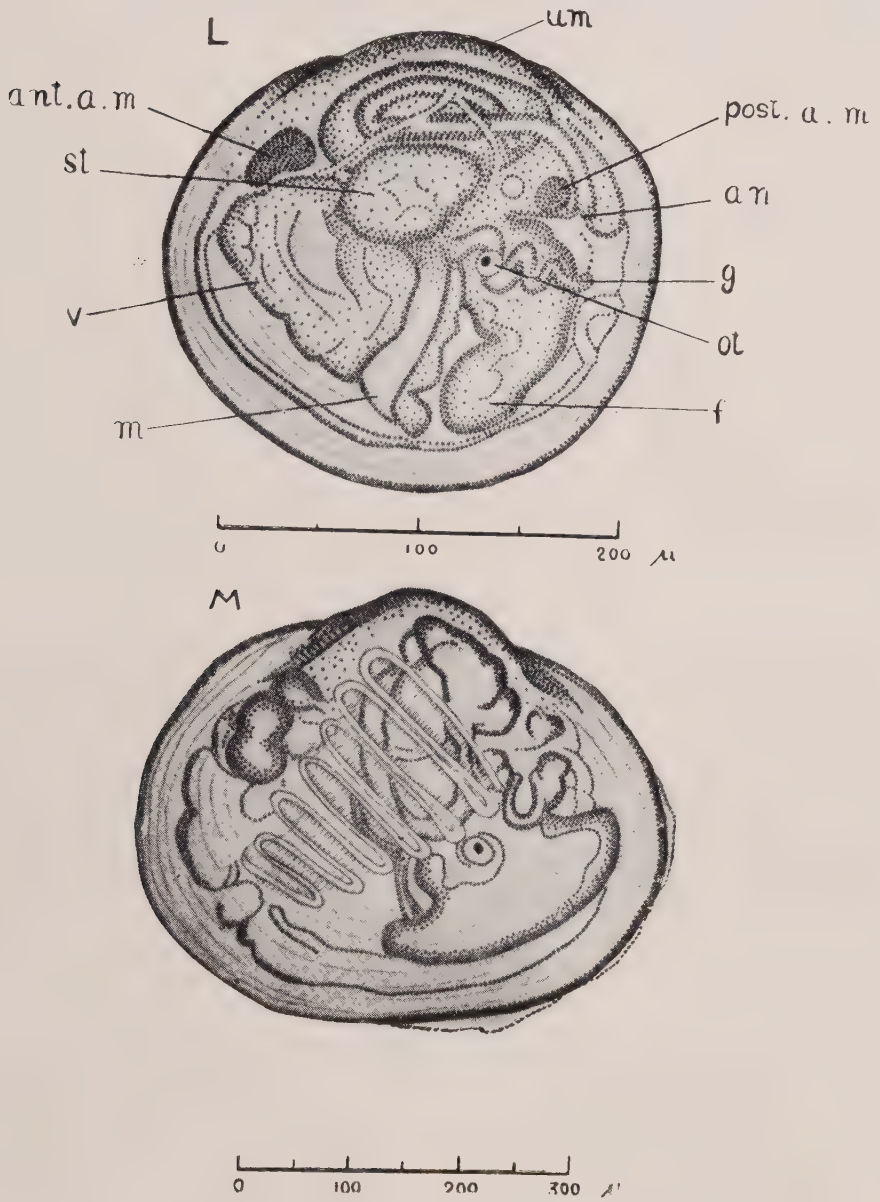

Fig. 2. Development of *Mactra sachalinensis*. 2.

L. Full grown veliger. M. Young. an.=anus ; ant. a. m.=anterior adductor muscle ; f.=foot ; g.=gill ; m.=mouth ; ot.=otocyst ; post. a. m.=posterior adductor muscle ; st.=stomach ; um.=umbone ; v.=velum.

as well as the period involving the early bottom life. The results of tank breeding and observations on the life history and behavior of the larvae are reported in this paper.

II. Material and Method

Material for the breeding experiment was collected at Isohama in Sendai Bay and at Koizumi beach, north of Onagawa. Large clams over 10 cm. in length were selected and used for this experiment. Artificial fertilization was accomplished in Petri-dish by adding sperm suspension to ripe eggs. Frequently over 90 per cent of the eggs were fertilized. As soon as the veliger larvae were obtained, they were transferred to outdoor tanks of the laboratory and were reared in stagnant water. The method of culture was practically the same as already reported in rearing oyster larvae in tanks (Imai et al,[2] 1950). The larvae were fed with a culture of *Monas* sp. No. 35, a non-colored naked flagellate, grown in the tank water.

III. Early Development

Matured eggs retained germinal vesicles (Fig. 1, A) which disappeared soon after the fertilization took place (Fig, 1, B). The diameter of matured eggs was from 70 to 75 μ. At the first cleavage no trefoil was formed and only a slight unevenness was noticed on the surface of the vegetative pole. At 15°C it required nearly 40 hours for the formation of the veliger larvae. The early veligers measured 90 to 100 μ in length and 70 to 80 μ in height (Fig. 1, J and Fig. 5, A). Time relation of early development at 15°C is shown in Table 1.

Table 1. Time relation of early development of *Mactra sachalinensis* at 15°C.

Stage of Development	Time after Fertilization
Formation of First Polar Body	40-50 min.
First Cleavage	1 1/2 hr. and over
Second Cleavage	2 1/2 hrs. and over
Third Cleavage	3 1/2 hrs. and over
Gastrula	12 hrs. and over
Trochophore	21 hrs. and over
D-Shaped Veliger	40 hrs. and over

IV. Temperaure and Salinity Conditions in Relation to Larval Development

In order to ascertain the temperature range wherein normal development could occur, the following experiment was carried out. Fertilized eggs were kept at six different thermostatic controlled temperatures — 32°C, 25°C, 22°C, 17°C, 13°C and 8°C. Over 80 per cent of eggs developed to normal veligers within the temperature range of 13 and 22°C. The result of experiment is summarized in Table 2. The range of temperature for normal development was slightly wider at lower limit as compared to the results reported by Kinoshita[3] (1934).

Table 2. Percentage of normally developed larvae at different temperature conditions.

Water Temperature °C	31.9±0.5	25.5±1.0	22.0±1.0	17.4±0.8	12.8±0.5	8.5±0.5
Percentage of						
Normal Egg Cleavage	0	83	100	97	100	84
Normal Gastrula	0	83	97	97	100	35
Normal Veliger	0	0	79	94	97	0

In the experiment wherein the fertilized eggs were kept at different chlorinity conditions, it was ascertained that the range of chlorinity in which normal development occurred was from 15.0 to 18.0 ‰ in chlorine. They failed to develop in waters with the chlorinity either above 21 ‰ or below 13 ‰.

V. Rearing Veliger Larvae in Tanks

Veliger larvae with a density less than 100 per litre of sea water were set in a concrete tank. The tank water was enriched with cooked soluble starch in order to maintain the density of food organism, *Monas* sp. at a level above 1,000 per cc. of water. The light intensity was reduced to 5 % of the direct intensity in order to restrain the colored phytoplankton at a low level. When the water was poured into the tank, it was rather rich in diatoms. Among them *Chaetoceras* sp. was the most abundant. The organisms gradually diminished in number and on 10th day after culture only a few were left in suspension. No succession of colored type of algae occurred during the period of the experiment.

Results of tank breeding in 1951 are summarized in Table 3 and the daily records of culture are shown in Figs. 3 and 4.

Table 3. Results of breeding experiment of *Mactra sachalinensis* in tanks in 1951.

Culture No.	1	2
Tank No.	C–5	C–4
Capacity in Litre	8,900	8,900
Number of Larvae set in Tank	400,000	550,000
Tank Water Condition		
Temperature °C	10.6 – 16.7	13.7 – 16.8
Chlorinity ‰	16.50– 16.93	18.06– 18.48
pH	8.13– 8.27	8.20– 8.27
Oxygen Saturation %	71.9 –110.1	85.8 –111.6
B.O.D. in p.p.m.	0.5 – 1.2	0.7 – 1.0
Number of *Monas* per cc.	500–6,200	300–3,300
Grams of Starch added (With Date of Enrichment)	5(14)	5(6), 5(9), 5(15), 5(18), 5(23)
Minimum Duration of Pelagic Life in Days	20	16
Estimated Number of Youngs of Bottom Life	250,000	200,000
Percentage of Survivals	53	36

Artificial fertilization of eggs was accomplished on 15 and 28, May. The rate of fertilization was 74 % and 60 % respectively. The resulting veliger larvae were set in the tanks on 17 and 19, May. The umbone began to develop when the shell reached about 130 μ in length and 110 μ in height (Fig. 5, B). The mortality of larvae was relatively high up to this stage of development, and this was considered to be a critical period in the larval development. The foot began to develop when the shell reached approximately 200 μ in length (Fig. 5, C). For a while the larvae either extended the foot to crawl on the substratum or extruded the velum to swim about in the water. When the foot had developed completely, the velum began to degenerate (Fig. 2, L and Fig. 5, D). The gill also showed itself at this stage of development. When larvae reached over 250 μ in height and 270 μ in length, the velum was completely lost and the clam entered upon the bottom life (Fig. 5, E). They never set on substratum by means of a bysus as is usually observed in other clams such as *Venerupis semidecussata* and *Meretrix meretrix lusoria*. We tried various type of collectors but none set on the cultch. It was observed under the microscope that the crawling young collect small sand grains and detritus on the shell surface, indicating the secretion of sticky substances from the body.

As soon as the *Mactra* began their bottom life, the shell form was gradually modified and became slightly elongated (Fig. 5, G). There was a linear relation between shell length and height for both the pelagic larvae and young living on the bottom (Fig. 6). For pelagic larvae, the relation is expressed by a formula : $L=H+21\ \mu$, where L and H were shell length and height in μ. For the young living on the bottom the relation is expressed : $L=1.22\,H-30\ \mu$. In a study on the dimentional character of Hokkaido *Mactra*, Kinoshita (1940) showed that

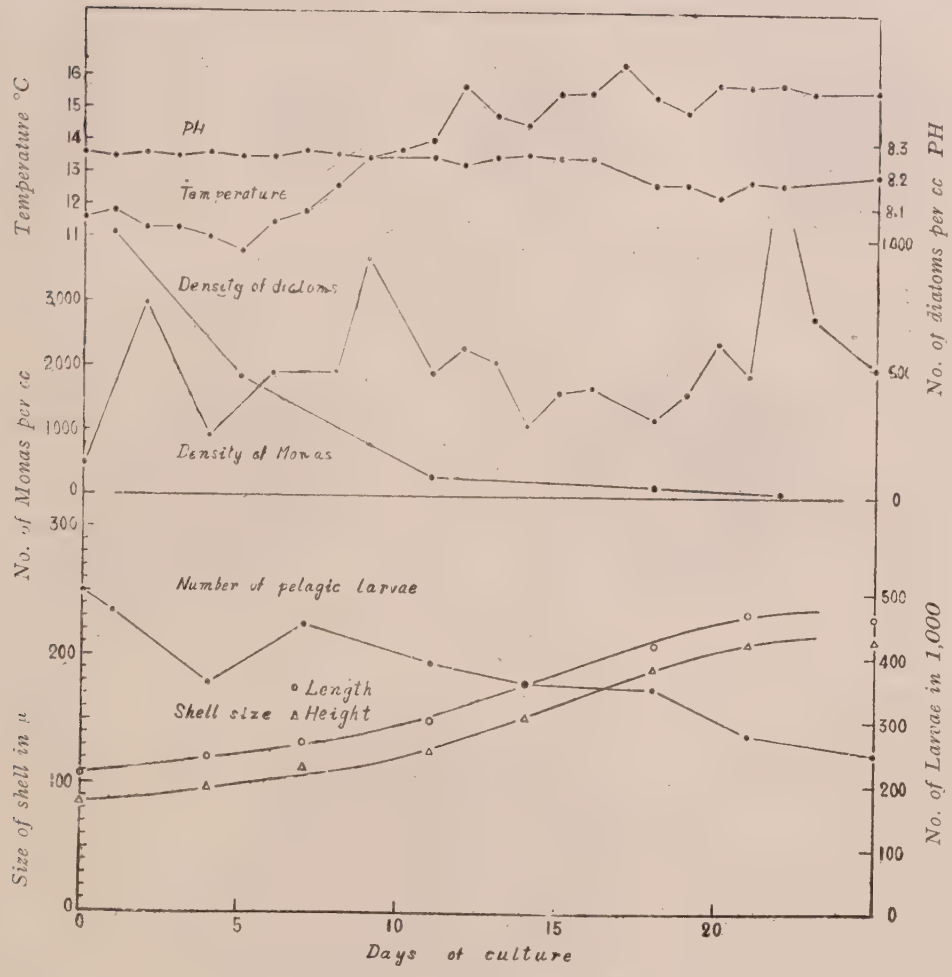

Fig. 3. Record of tank breeding of *Mactra sachalinensis*. Culture No. 1.

in specimens over 2 years old, shell length and height relationship was expressed by a formula : L=1.23 H. Our measurement on young *Mactra sachalinensis* is very close to his finding. It is suggested from the result that the pattern of the adult shell form (length-height relation) is attained as soon as the young begins its bottom life and is never thereafter changed.

IV. Collection of Seeds

As already mentioned, larvae of *M. sachalinensis* never set on the substratum during their transformation from pelagic life to bottom life. Therefore the

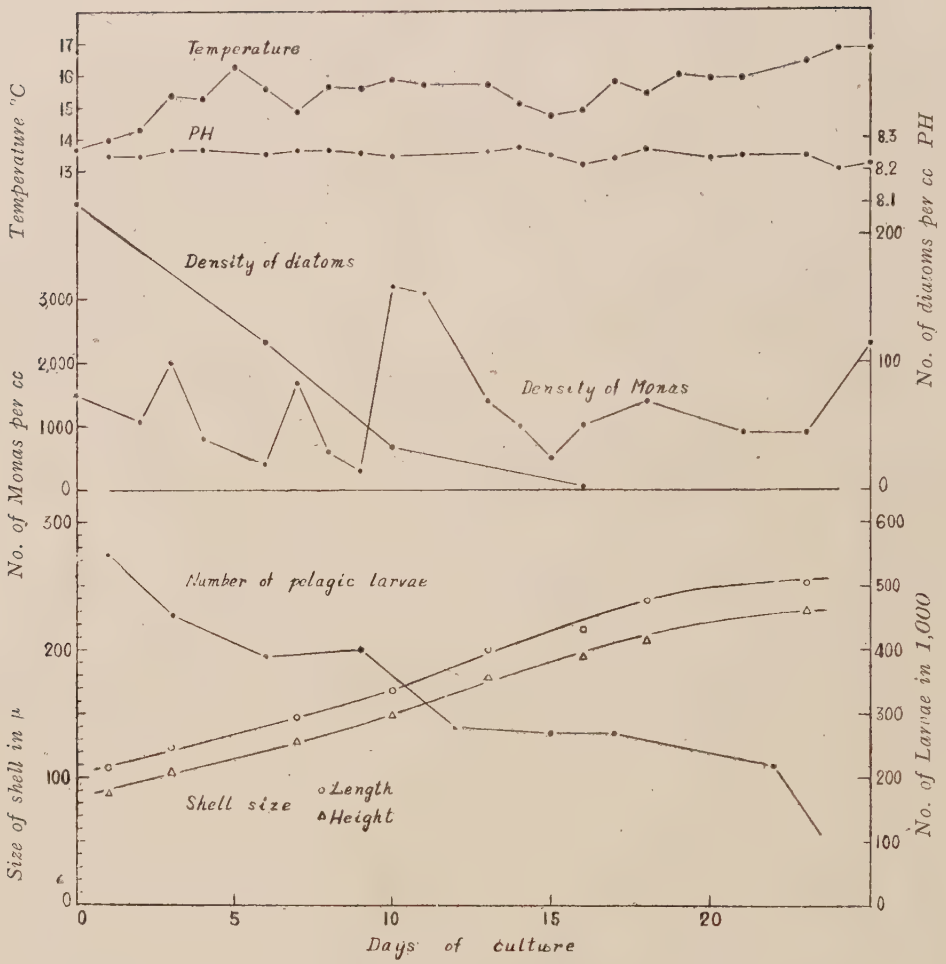

Fig. 4. Record of tank breeding of *Mactra sachalinensis*. Culture No. 2.

young must be collected from the bottom of the tank. In order to accomplish this, the top water of the tank was drained off and then the young were collected by draining the bottom water through a sieve. Over a million of seeds colllected in this way have been transplanted to beaches such as Iso-hama, Naga-hama and Onagawa Bay during the past five years.

Because of the troublesomeness in collecting the seed and also the difficulties in raising the seed large enough for successful transplantation, under protected condition, the breeding of seeds in tank may not be applied for commercial production at present. Nevertheless, the tank breeding can offer an effective means to study the life history and ecology of clam larvae and young.

Fig. 5. Developmental stage of shell of *Mactra sachalinensis*.

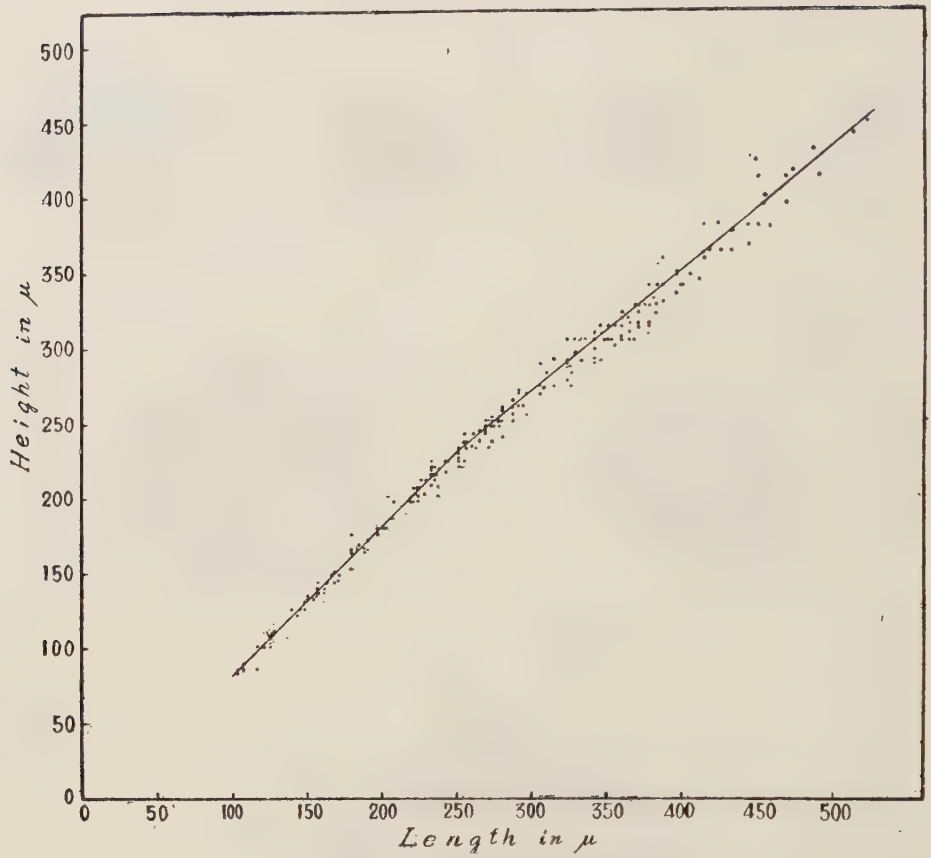

Fig. 6. Length-height relation of shells of pelagic larvae and youngs of bottom life.

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Notes on the Polychaetous Annelid, *Polydora* in Oysters Under Raft Culture*

Seiichi SAKAI

(Received December 10, 1952)

I. Introduction

Polychaetous worm of the Genus *Polydora*, or mud worm, had long been considered as a destructive enemy of the oyster. Sometimes it was suspected to be responsible for the complete disappearance of oysters in some of large beds. For example, Whitelegge[9] (1890) and Roughley[6][7] (1922, 1925) reported such damages that were possibly caused by *P. ciliata* in Australian waters.

Several species of *Polydora* have been reported to infest and give damages to oysters and other mollusks by Takahashi[8] (1937), Nelson and Stuber (1940), Kavanagh (1940), Lunz[1][2] (1940, 1941) and Loosanoff and Engle[1] (1943). Some of the investigators claim that the mollusks infested with *Polydora* gradually grow weak and eventually succumb. The mollusks living on the bottom layer are said to be infested more easily by the mud worm than those living above the bottom. Therefore, Roughley (1922, 1925) considered that keeping the oyster off the bottom mud is an effective means for preventing the infestation.

I found many mud worms, *P. ciliata*, in the shell layer of the Japanese oysters, *O. gigas*, which were cultured under the raft, off the bottom, in Onagawa Bay, Miyagi Prefecture. They gave ill effects on their growth and fattening. I will report herein the results of the morphological and ecological observations on the mud worms found in Onagawa Bay and their effects on cultured oysters.

I wish to express my hearty gratitude to Prof. T. Imai for his supervision throughout the present work.

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* The 88th report of the Institute for Agricultural Research, Tohoku University (1952) and Contribution from the Onagawa Fisheries Laboratory.

II. Description of *Polydora ciliata* (JOHNSTON)

The worm is yellowish brown in life. In large specimens, the body reaches 25 mm. in length and has about 100 segments. The prostomium is cuneiform and consists of two lobes with a shallow cleft at its anterior end; the posterior margine of the nuchal ridge reaches to the posterior end of the 2nd chaetigerous segment. Four eyes in trapezoidal arrangement are recognized. Peristomium has a pair of long and slender whip-like tentacles on the dorsum. The tentacles reach to about the 15th chaetigerous segment. Anterior parts of the body in dorsal view are shown in Fig. 1 a.

Branchiae begins at the 7th chaetigerous segment; it is at first small, but it gradually enlarges and attains full size at about the 12th segment. It disappears at about the 15th segment from the pygidium.

The 5th chaetigerous segment is wide and has modified hooks (Fig. 1 d). The ventral hooded crockets begin at the 7th chaetigerous segment (Fig. 1 c). They have two well developed teeth, the major one being at a right angle to the shaft. Pygidium is cup-like in outline and the anus opens dorsally (Fig. 1 b).

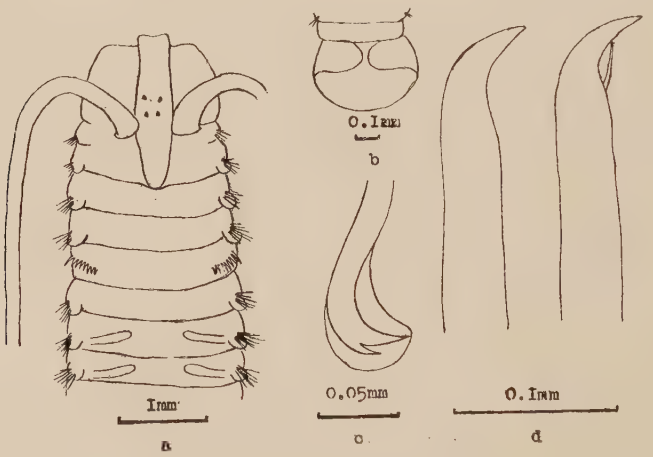


Fig. 1. Showing certain morphological characters of *P. ciliata*. a, Anterior parts. b, Pygidium. c, 7th ventral hooded crocket. d, 5th modified hooks.

III. Observations

To make observations on the mode of infestation by the mud worm on

oysters cultured under the raft, 96 oyster spats, free from mud worms, were placed in a wire cage suspended in the water under a raft two meters deep in Onagawa Bay, in April 1950. The dimension of the cage was 50 centimeters in length and breadth and 13 centimeters in depth. The fouling organisms such as the mussel, barnacle, bryozoa, sponge and new oyster spats were removed from the surface of the oyster shells with a knife and hair-brush once or twice every month. These oysters were kept in water until December 10, 1951. Thus, the period of culture covered one and a half years, including one winter and two summers. Thirty-six oysters were alive at the end of culture. All the living shells were then opened and the conditions of their shells and soft parts were examined.

Examination of the shells revealed that all of the oysters were infested with *P. ciliata* (Table 1). In Table 1, the shells are classified into three groups A, B and C according to the numbers of mud tubes countable from the inside of the shell. The shells of group A were those in which no mud tubes were recognized on the inner-surface though there were innumerable holes on their outer-surface. Group B were those in which less than ten tubes per ten grams of wet shell weight were counted. Group C were those with more than ten tubes per ten grams of wet shell weight. In the most heavily infested shell, nearly 70 tubes were counted per 10 grams of shell. No special swelling, called "blister" by Y. Masagaki[4] (1936) was observed at the terminus of the mud tube. Infestation occurred equally in the cup valves and flat valves of the shells, as is seen from Table 1.

Table 1. Average number of mud tubes counted on the inner-surface of the oyster shells.

Group	Number of oyster	Average number of mud tubes per shell			Average number of mud tubes per 10 gr. of wet shell weight		
		cup valve	flat valve	total	cup valve	flat valve	total
A	10	0	0	0	0	0	0
B	13	8	8	16	2.4	3.0	2.7
C	13	64	61	125	24.8	30.3	27.6

Having found a heavy infestation among the oysters, the relation between the extent of infestation and the growth and fattening of these animals was examined. For this purpose, a comparison was made on the conditions of the shells and soft parts among the three groups of oysters classified by the degree of infestation (Table 2). The oyster meat of group A was in excellent condition (Fig. 2 a). Group B showed that, though a few mud tubes were recognized from the inside of the shells, the meat was also in excellent condition similar to that of group A. On the contrary, the meat of group C were extremely thin in contrast to those

of A and B (Fig. 2 b). In C group, the meat was watery and the digestive diverticula was visible through the meat. The dry weight of their meat was only 0.9 percent of their total weight while that of group A and B were 2.2 and 2.1 percent respectively. The difference was marked and statistically significant. The water contents of the meat were 92.3 percent against 85.5 and 86.3 percent of the groups A and B. It is worthy of note that the glycogen content of meat was very low being only 3.8 percent of their dry weight while in groups A and B it was 13.5 and 13.3 percent respectively.

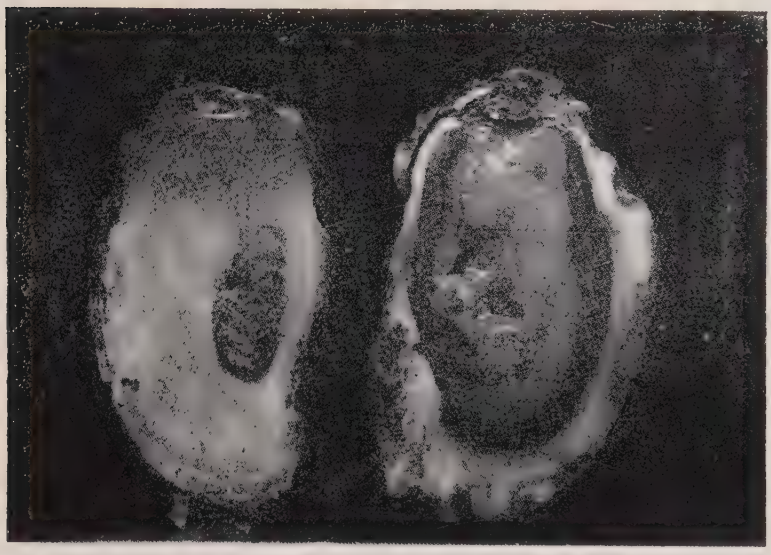
Table 2. Effect of worm infestation on oysters.

Characters of oyster	Groups of oyster		
	A	B	C
	Mean±St. dev.	Mean±St. dev.	Mean±St. dev.
Height (mm.)	83.7± 9.56	85.5± 9.06	80.7± 9.61
Volume (cc)	63.7±16.45	62.6±10.64	53.5±10.05
Total weight (gr.)	109.6±29.02	104.8±17.44	82.8±16.13
Wet weight of shell (gr.)	79.5±23.68	72.6±12.19	55.8±12.05
Wet weight of meat (gr.)	16.4± 3.32	16.3± 3.97	9.7± 2.88
Dry weight of meat (gr.)	2.4± 0.59	2.3± 0.88	0.8± 0.48
Percentage of dry meat wt. to total wt.	2.2± 0.22	2.1± 0.42	0.9± 0.47
Water content of meat (%)	85.5± 1.97	86.3± 2.14	92.3± 2.80
Glycogen in dry basis (%)	13.5	13.3	3.8

From these observations a conclusion may be drawn that infestation with *P. ciliata* does not necessarily render the oyster poor, but in case of heavy infestation, an extremely poor meat will be the result.

There is left a question whether a heavy infestation causes a high mortality among the oysters. In the experiments above mentioned, I started the culture with ninety-six oysters in April of 1950. Fourty of them were killed by mechanical impediments during the period of culture. At the end of the experiment, in December 1951, thirty-six of these oysters were still alive. Twenty oysters died naturally during the period. Among them, only three oysters showed heavy infestation. If these three died as a result of infestation of the mud worm, the mortality due to infestation would be 5.3 percent of the cultured oysters while that due to other reasons was 30.4 percent. Therefore, the mortality due to mud worm infestation seems to be rather low as compared to other causes.

An experiment was carried to see the boring activity of the mud worms. The infested shells from which the meat was removed were put in a cage and then suspended under a raft in the water of Onagawa Bay on December 27, 1951. As is shown in Table 3, there occured a rapid increase in the number of tubes on the inner-surface of the shell indicating the active boring of the worm even in the low



a

c

Fig. 2. Condition of oyster meat in Group A (a) and C (c). Mud tubes are see in the shell of Group C.

water temperature.

Table 3. The increase of number of the mud tubes on the inner-surface of shell.

Date of observation	W.T. °C	Shell number						
		1	2	3	4	5	6	Total
Dec. 27, 1951	10.7	0	0	0	7	14	23	44
Jan. 14, 1952	9.6	6	24	6	16	41	34	127
Feb. 8, 1952	9.9	7	32	8	20	52	36	155

IV. Discussion and Conclusion

It has been generally considered that several species of polychaetous worms are destructive enemies of mollusks. Whitelegge and Roughley have recorded that *P. ciliata* disturbed the fattening and growth of oysters, and often caused a heavy mortality in Australian waters. They also stated that a heavy infestation with mud worms can be avoided if the oysters were kept off the bottom.

However, the present observations proved that the oysters were infested heavily by *P. ciliata* even when they were suspended under a raft, off the bottom, in Onagawa Bay. I could not examine the infestation in the bottom oysters in the bay, because they were not available. Neverthless, it leaves no room to doubt that the oyster under a raft can not escape the heavy infestation by mud worms.

Such results coincide with the finding of Loosanoff and Engle (1944) on the infestation of the oysters with *P. websteri* in Milford Harbour. They also stated that "a heavy infestation with *P. websteri* does not necessarily interfere with the feeding and fattening of oysters, nor impair their growth". As already mentioned, the present experiments have proved clearly that though an infestation with *P. ciliata* does not necessarily interfere with the growth and fattening of oysters, an extremely heavy infestation certainly effects the oysters.

Such an ill effect may occur only when *Polydora* bores so deep in the shells reaching to the inner-surface. In such occassions, many factors will be considered as to threaten the oyster's well to do, such as mechanical irritation, the excretion of some toxic substances and the comsumption of energy in secreting the shell material to cover the opening of mud tubes. Healthy oysters may easily seal up the *Polydora* burrows when they are few. However, when the mud tubes become extremely numerous, and the oyster gets too weak to react promptly to seal up the burrows, the oyster seems to suffer much from the activities of the mud worm.

It is reported by Lunz (1941) and Loosanoff (1943) that *P. ciliata* and *P. websteri* prefer water of low salinity. I collected many mud worms, *P. ciliata*, from the oyster shells under the raft culture in Onagawa Bay, where the salinity above 28.5 ‰ prevails almost throughout the year. On the contrary, very few oysters from Mangoku-Ura were found infested with *Polydora*. Mangoku-Ura is an inlet situated nearly five miles from Onagawa Bay. The salinity of the inlet is usually lower than Onagawa Bay and it falls to 20.0 ‰ or less during the rainy season. Such fact seems to suggest that the survival and propagation of the mud worm is controled by the fluctuation of salinity.

V. Summary

1. The infestation of oysters by raft culture with the polychaetous worm and its effect on the growth and fattening of the oyster were examined in Onagawa Bay, Miyagi Prefecture.
2. The shells of oysters cultured in a wire cage hung under a raft were found to be heavily infested with *Polydora ciliata* (Johnston).
3. *P. ciliata* does not necessarily interfere with the growth and fattening of oysters, but in case of extremely heavy infestation, both the growth and fattening were disturbed considerably.
4. The mortality due to the infestation with the *P. ciliata* was relatively low and it amounted to only 5.3 percent of the cultured oysters.

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